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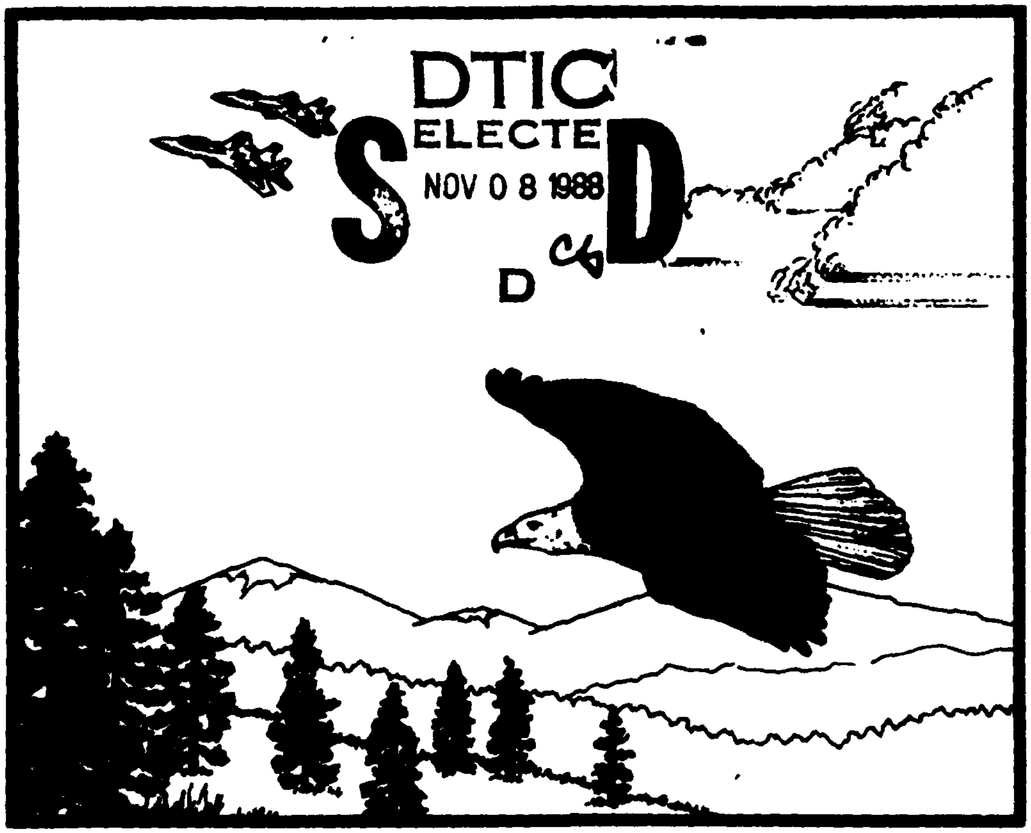
EFFECTS OF AIRCRAFT NOISE AND SONIC BOOMS ON DOMESTIC ANIMALS AND WILDLIFE: BIBLIOGRAPHIC ABSTRACTS



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The purpose of this document is to provide an information base on the effects of aircraft noise and sonic booms on various animal species. Such information is necessary to assess potential impacts to wildlife populations from proposed military and other flight operations.

To develop this document the National Ecology Research Center conducted a literature search of information pertaining to animal hearing and the effects of aircraft noise and sonic booms on domestic animals and wildlife. Information concerning other types of noise was also gathered to supplement the lack of knowledge on the effects of aircraft noise. The bibliographic abstracts in this report provide a compilation of current knowledge. No attempt was made to evaluate the appropriateness or adequacy of the scientific approach of each study.

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EFFECTS OF AIRCRAFT NOISE AND SONIC BOOMS ON DOMESTIC ANIMALS AND WILDLIFE: BIBLIOGRAPHIC ABSTRACTS

By

Douglas N. Gladwin
U.S. Fish and Wildlife Service
National Ecology Research Center
Fort Collins, CO 80526-2899

Karen M. Manci
TGS Technology, Inc.
Fort Collins, CO 80526-2899

and

Rita Villella
U.S. Fish and Wildlife Service
National Ecology Research Center
Kearneysville, WV 25430

U.S. Fish and Wildlife Service
National Ecology Research Center
Fort Collins, CO 80526-2899

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PREFACE

This report was produced as the result of a cooperative research project between the National Ecology Research Center, Ft. Collins, CO and the Air Force Engineering and Services Center, Tyndall Air Force Base, FL, on the effects of aircraft noise and sonic boom on animals. The effort was funded by the Air Force's Noise and Sonic Boom Impact Technology program, Wright-Patterson Air Force Base, OH.

INTRODUCTION

The U.S. Air Force must be able to conduct flight operations in assigned airspace over public and private lands to train personnel and test new technologies to fulfill its National defense mission. The Air Force can only fulfill its mission by maximizing use of current aircraft operating areas and varying military training routes to give pilots added experience. Acquiring and maintaining new airspace is vital in light of increasing mission requirements and international agreements. These actions will impose aircraft noise on the environment which may affect wildlife; thus these actions fall under the auspices of the National Environmental Policy Act (NEPA) of 1969. NEPA requires all Federal Government agencies to analyze the environmental impact of proposed Federal actions "significantly affecting the quality of the human environment" (42 USC 4341).

A great deal of research was conducted during the 1960's and 1970's to determine the likely effects of commercial supersonic jet aircraft on the environment, focusing on the effects on humans, due to public fear of adverse ecological impacts. However, the knowledge gained from this research does not apply directly to wildlife on areas overflown by aircraft at supersonic speeds and at low altitudes.

Although scientists have researched some effects of noise on animals, any data gaps still exist on the overall effects of aircraft noise on wildlife. In addition, perceived inadequate or inaccurate analysis of the effects of aircraft noise on wildlife by the general public has resulted in delays of flight operation expansion.

To develop this document the National Ecology Research Center conducted a literature search of information pertaining to animal hearing and the effects of aircraft noise and sonic booms on domestic animals and wildlife. Information concerning other types of noise was also gathered to supplement the lack of knowledge on the effects of aircraft noise. The bibliographic abstracts in this report provide a compilation of current knowledge. No attempt was made to evaluate the appropriateness or adequacy of the scientific approach of each study.

The purpose of this document is to provide an information base on the effects of aircraft noise and sonic booms on various animal species. Such information is necessary to assess potential impacts to wildlife populations from proposed military and other flight operations.

BIBLIOGRAPHIC ABSTRACTS

Acoustical Society of America. 1980. San Diego workshop on the interaction between manmade noise and vibration and Arctic marine wildlife. Acoust. Soc. Am., Am. Inst. Physics, New York. 84 pp.

The Acoustical Society of America held a workshop in 1980 to assess the potential hazards of manmade noise associated with proposed Alaska Arctic (North Slope-Outer Continental Shelf) petroleum operations on wildlife and to prepare a research plan to secure the knowledge necessary for proper assessment of noise impacts. Noise sources identified as most likely to affect wildlife were seismic pulse generators; helicopters and other aircraft; surface vessels, such as tugs and work boats; and vehicles on land and ice, such as trucks, tractors, and snowmobiles. Other possible sources were oil well drilling, island and causeway building, and petroleum and gas production and processing. The known effects of noise on Arctic wildlife are limited; however, noise disturbance to birds has been documented. Nesting common eiders (Somateria mollissima) have been disturbed by low-flying, small, fixed-wing aircraft and by helicopters. Recent experiments and experience have shown that the lesser snow goose (Anser caerulescens) is sensitive to aircraft disturbance. Low-level (150 m AGL) aircraft overflights elicited a stronger response from molting, flightless sea ducks [particularly, oldsquaw (Clangula hymalis)] than did higher level overflights. Little data have been collected on the effects of noise on marine mammals. Beluga whales (Delphinapterus leucas) are more easily displaced by boat traffic when feeding. Bowhead whales (Balaena mysticetus) appear more wary of noise during spring compared to during autumn. Marine mammals are highly acoustically oriented, and more research is needed to assess the potential impacts of noise on these species. Assessment of the expected noise impacts on Arctic wildlife requires much additional data on noise sources, noise propagation in the Arctic environment, general ambient noise conditions, physical environmental factors, and species response to such noise. A scientific research plan is presented, with priority indicators, to obtain the needed data.

Algers, B., I. Ekesbo, and S. Stromberg. 1978. The impact of continuous noise on animal health. Acta Vet. Scand. Suppl. 67. 26 pp.

This paper reviews the literature on continuous noise and its effects on animals. The term "continuous noise" was used to indicate noise that is not intermittent in nature and not characterized by short sound blasts. The review mainly covers research carried out on laboratory animals because few observations of continuous noise on farm animals have been made. Effects of noise on behavior and various organ systems, hormonal systems, and immunology are discussed.

Altes, R.A. 1973. The Fourier-Mellin transform and mammalian hearing. J. Acoust. Soc. Am. 63:174-183.

A combined Fourier-Mellin transform yields a representation of a signal that is independent of delay and scale change. Such a representation should be useful for speech analysis where delay and scale differences degrade the performance of correlation operations or other similiar measures. At least two different versions of a combined Fourier-Mellin transform can be implemented. The simplest version completely eliminates spectral phase information, while a slightly more complicated version preserves some phase information. Both versions can be synthesized with a Fourier-Mellin transform and an exponential-sampling algorithm. Exponential sampling produces a frequency scale distortion that is similiar to the effect of the cochlea. The transform also can be implemented with a bank of proportional band-width filters. If the relative phase between spectral components is preserved, then a Fourier-Mellin transform can perform compression of linear-period modulated signals. Such signals are used for echolocation by bats and cetaceans. The same approach that gives scale and delay invariance can be used to obtain other transform combinations that provide insensitivity to a variety of distortions. The combined tranforms can also be used for analyzing these distortions.

Ames, D.R. 1978. Physiological responses to auditory stimuli. Pages 23-45 in J.L. Fletcher and R. G. Busnel, eds. Effects of noise on wildlife. Academic Press, New York.

The auditory threshold for sheep was determined by changes in EEG patterns and behavior responses. Effects of three types of noise, at different intensities, on heart and respiration rates, growth, digestion, and reproduction indicated a differentiation between sound type and intensity. Although physiological changes were observed, results suggested that the sheep acclimated to sound.

Ames, D.R. 1971. Thyroid responses to sound stress. J. Anim. Sci. 33:247. [Abstract.]

Ten growing lambs were subjected to two intensities (75 and 90 dB) of white noise to evaluate the effects of sound intensity on thyroid function. Each animal was exposed to a control period (63 dB background), followed by treatment periods of 75 and 90 dB. Each exposure, including the control was for 3 weeks. Results indicated that sound intensities of 90-dB white noise inhibited the release of thyroid hormones; no differences were detected between the 75-dB and control group.

Ames, D.R., and L.A. Arehart. 1972. Physiological response of lambs to auditory stimuli. J. Anim. Sci. 34:994-998.

Auditory thresholds were determined for 10 Suffolk ewe lambs. EEG pattern changes and behavioral responses were highly correlated with hearing thresholds. The audiogram for sheep was similiar in shape to that for humans, but at a higher frequency (most sensitive at 7,000 Hz). Lambs were exposed to different noise types and levels; heart rate and respiratory rates were measured. Differentiation to sound type and level was apparent as well as acclimation to sound.

Anonymous. 1969. Spectrum: The death of birds...(news release). Environment 11(6):S-1.

Biologists at the Fort Jefferson National Monument at the southern tip of Florida have recorded a major reproductive failure among sooty terns (Sterna fuscata); 98% of the population of 40,000 terns failed to reproduce successfully in 1969. Reproduction among other bird species, including other terns, was normal that year. According to Boyd Evison of the National Park Service, some specialists think that sonic booms may have caused the nesting failure.

Anthony, A., and E. Ackerman. 1957. Biological effects of noise in vertebrate animals. Tech. Rep. 57-647. Wright Air Develop. Center, Wright-Patterson Air Force Base, Ohio. 98 pp.

The stress effects of noise on bodily functions other than hearing were studied in laboratory rodents. Physiological, biochemical, and behavioral effects of intense noise at low and high frequencies were examined using (1) flame spectrophotometric analysis of serum electrolytes; (2) serum ascorbic acid and blood sugar changes; (3) changes in adrenal and plasma cholesterol; (4) behavioral changes in noise-exposed rats, mice, and guinea pigs; and (5) relationship of seizure-susceptibility to noise stimulation. A corona speaker was designed and constructed for use in acoustic studies. Short, daily exposures to intense noise of about 132- to 140-dB pressure levels induced physiological stress in rats, mice, and guinea pigs by increasing adreno-cortical activity (manifested in "anxiety-like" behavior) under stimulation at low frequencies (150-4,800 Hz) and increasing audiogenic seizures at high frequencies (2-40 kHz). Animals appeared to adapt somewhat to noise stress; however, the fact that noise elicits a defense response makes it reasonable to assume that high levels of acoustic noise will overtax the homeostatic adaptive mechanisms. Considerable work will be necessary to define the tolerance limits of animals to noise, both alone and in situations where noise is only one of several stressful stimuli.

Anthony, A., and E. Ackerman. 1955. Effects of noise on the blood eosinophil levels and adrenals of mice. J. Acoust. Soc. Am. 27:1144-1149.

Physiological changes are described following exposure of mice to single and intermittent noise stimulation of 110 dB for varying lengths of time. Attention is focused on the degree of adrenocortical activation as measured by cytological changes in the adrenal gland and decrease in the number of circulating eosinophils. Because the observed changes were transient, the noise was described as not harmful.

Anthony, A., E. Ackerman, and J.A. Lloyd. 1959. Noise stress in laboratory rodents. I. Behavioral and endocrine responses of mice, rats, and guinea pigs. J. Acoust. Soc. Am. 31:1430-1437.

Mice, rats, and guinea pigs were exposed daily to high-intensity noise in the frequency range of 150-4,800 Hz in these three species. The adrenal response supports the interpretation that noise acts as a physiological stress, but does not induce harmful nonauditory effects.

Arehart, L.A., and D.R. Ames. 1972. Performance of early-weaned lambs as affected by sound type and intensity. J. Anim. Sci. 35:481-485.

Early-weaned lambs were subjected to three types of noise at 75 and 100 dB. Noise at 75 dB increased average daily weight gain and improved feed efficiency compared to controls and the 100-dB group. Acclimatization to sound was evident. Lambs exposed to music were calm and more docile compared to lambs subjected to intermittent sound and noise. Neural and neuroendocrine systems are possible mechanisms for the effects of noise on feed efficiency.

Austin, O.L., Jr., W.B. Robertson, Jr., and G.E. Woolfenden. 1970. Mass natching failure in Dry Tortugas sooty terns (*Sterna fuscata*). Page 627 *in* K.H. Voous, ed. Proc. 15th Int. Ornithol. Cong. The Hague, Netherlands. [Abstract.]

In 1969, approximately 50,000 pairs of sooty terns (*Sterna fuscata*) returned to nest in the Dry Tortugas colony in southern Florida, laid their eggs, and started incubating normally. When the authors arrived in mid-June to band young, they found 242 sooty chicks instead of the normal 20,000-25,000 chicks. About half the normal number of adults were still present, and they were markedly wild and restless. Apparently, only a few of the earliest-laid eggs had hatched, a few eggs were still being incubated, and the rest were deserted and contained dead, partly grown embryos. The colony also contained approximately 2,500 brown noddies (*Anous stolidus*) whose young hatched successfully. Most possible causes of the sooty terns' nesting failure were ruled out, with the exception of an overgrowth of island vegetation (which made it difficult for sooties to reach their nests in the more populous sectors) and frequent sonic booms by jet planes. The booms were almost a daily occurrence, and some were strong enough to shatter windows on adjoining Garden Key. Birds reacted to the occasional sonic booms of previous seasons by rising immediately in a "panic flight," circling over the island momentarily, and then usually settling down on their eggs again. The authors had no evidence that sonic booms caused physical damage to the sooty tern eggs, but felt that the strong booms occurred often enough to disturb the sooties' incubating rhythm and cause nest desertion. Actions were taken to curb planes breaking the sound barrier within range of the Tortugas, and much of the excess vegetation was cleared. In mid-May 1970, the birds appeared to be having a normal nesting season

Banner, A., and M. Hyatt. 1973. Effects of noise on eggs and larvae of two estuarine fishes. Trans. Am. Fish. Soc. 102:134-136.

A simple apparatus was devised to expose eggs and larval fishes to moderate and high noise levels (up to +20 dB/µb), holding other conditions constant. Viability of eggs and resulting sheepshead minnow (*Cyprinodon variegatus*) larvae was significantly reduced in the noisier tank. Lethal effects of noise were apparently restricted to embryonic *C. variegatus*; fry exposed subsequent to hatch experienced no losses. Growth rates of *C. variegatus* and longnose killifish (*Fundulus similis*) larvae were significantly greater in the quieter tank under both 8L:16D and 16L:8D photoperiods. Fishes experiencing the longer photoperiod were somewhat shorter, but significantly heavier than those under the shorter photoperiod for the respective noise conditions.

Bastian, V.H. 1984. The influence of quality and sound pressure of acoustic signals on heart rate of chiffchaff (*Phylloscopus collybita*). Die Vogelwarte 32(4):249. [English summary.]

In a series of experiments, 21 male chiffchaffs (*Phylloscopus collybita*), wild-caught and hand-reared, were played back songs of their own and alien species to test the influence of the songs' sound pressure on heart rate. Hand-reared birds reacted more often to played-back songs than wild-caught birds. Neither group showed a preference for songs of its own or alien species. Songs with a sound pressure of 70 dB constantly elicited an alteration of heart rate and a conditioning for time after the end of the song's sequence. Songs with a sound pressure of 50 dB neither effected any conditioning nor a constant alteration of heart rate. The measurement of the heart rate for the chiffchaff did not appear to be a suitable method to quantify the efficiency of species-specific stimuli.

Beecher, M.D., P.K. Stoddard, and P. Loesche. 1985. Recognition of parents' voices by young cliff swallows. Auk 102:600-605.

Cliff swallow (*Hirundo pyrrhonata*) chicks, 9 and 18 days old, were played calls (2.1-4.2 kHz) of parents and unrelated (control) adults. Younger chicks showed no difference in the frequency of their antiphonal begging calls to parental versus control calls. The older, near fledgling chicks, however, responded significantly more to parental calls than to control calls; 78% of their total antiphonal calls were in response to parental playback calls. In these older chicks, the degree of preference calls correlated with the measured acoustic differences between the parent and control calls. Results indicated that cliff swallow chicks were able to recognize their parents by voice before they left the nest. Offspring recognition of parents is discussed as it relates to the evolution of parent-offspring recognition systems in general.

Bell, W.B. 1972. Animal response to sonic booms. J. Acoust. Soc. Am. 51:758-765.

This paper reviews reports and studies of animal response to sonic booms. Individual domestic or pet animals may react to a boom; a simple startle response is the most common reaction. However, specific reactions differ according to the species involved, whether the animal is alone, and perhaps whether the animal has been previously exposed to sonic booms. Trampling, moving, raising the head, stampeding, jumping, and running are among the reactions reported. Birds occasionally run, fly, or crowd. Reactions vary from boom to boom and are not predictable. Animal reactions to booms are similar to their reactions to low-altitude subsonic aiplane flights, helicopters, and sudden noises. Conclusive data on effects of booms on production are not available. The effect of booms on eggs hatched under commercial conditions was examined in detail, and no effects on hatchability were found. However, a mass hatching failure of Dry Tortugas sooty terns (Sterna fuscata) occurred in 1969, and circumstantial evidence suggests that physical damage to the eggs by severe sonic booms caused by low-altitude supersonic flights was responsible. Observations on wild and zoo animals are limited, but those made on ungulates and some zoo animals revealed no reaction or only minimal and momentary reaction, such as raising the head, pricking the ears, and scenting the air. The author suggests further studies on the effects of sonic booms on each domesticated species and on wildlife in its native habitat.

Bender, A. 1977. Noise impact on wildlife: an environmental impact assessment. Pages 155-165 in Proceedings of the 9th Conference on Space Simulation. NASA(P-20007).

Due to scarcity of data, environmental impact assessments rarely consider the noise effects on wildlife. A complete and accurate assessment of a given impact should include an assessment of how animals will react to various noise levels of varying frequencies produced by the impact. However, this type of information is presently unavailable for most situations; at best, information can only be extrapolated from laboratory experiments and limited field observations. Various biological effects of noise on animals are briefly discussed and a systematic approach for an impact assessment is developed. Further research is suggested to fully quantify noise impact on individual species and their ecosystem.

Berger, J., D. Daneke, J. Johnson, and S.H. Berwick. 1983. Pronghorn foraging economy and predator avoidance in a desert ecosystem: implications for the conservation of large mammalian herbivores. Biol. Cons. 25:193-208.

Assumptions of optimal foraging theory were applied to the feeding ecology of pronghorn (Antilocapra americana) to address issues of immediate relevance to conservation biology in the Great Basin Desert of North America. The relationships between foraging efficiency and: (1) group size, (2) habitat, and (3) disturbance history were examined on two study sites. Individual foraging efficiency increased with group size, to a point, in both study sites, but animals in the disturbed (by hunting, mining, construction) area remained in larger groups despite foraging less profitably. The hypothesis that individuals in a disturbed environment remain together for enhanced protection from predators was supported and interpreted in the light of proposed habitat alterations in vast portions of this unique desert ecosystem.

Beulig, A. 1982. Social and experiential factors in the responsiveness of sharks to sound. Fl. Sci. 45(1):2-10.

The capacity of sharks to detect and respond to underwater sound has been well established. In previous studies, sharks were attracted most readily by broad-band, low-frequency, irregularly pulsed sounds of 20-100 Hz. To investigate the possibility that sharks are attracted to biologically significant sounds (such as accelerating schools of fish, injured and struggling fish, and feeding animals) that exist in the frequency range below 20 Hz, responses of juvenile lemon sharks (Negaprion brevirostris) to low-frequency (12.5 Hz), irregularly pulsed sounds were measured. The sharks were born in captivity and deprived of normal prey-capturing experience and social interaction with wild sharks. Initially, the juvenile sharks, tested individually, were not attracted to the low-frequency sounds, even after opportunities to capture living prey and to experience auditory stimulation associated with wounded, struggling fish were provided. When the sharks were tested in groups of three, their approach-response level indicated attraction to the low-frequency sound and results compared favorably with juvenile sharks that had species-typical feeding and rearing experience. Thus, the existence of a social factor in response to sounds was verified.

Black, B.B., M.W. Collopy, H.F. Percival, A.A. Tiller, and P.G. Bohall. 1984. Effect of low-level military training flights on wading bird colonies in Florida. Florida Coop. Fish Wildl. Res. Unit, Sch. For. Res. Conserv., University of Florida, Gainesville. Tech. Rep. 7. 190 pp.

The effect of low-level military training flights on the establishment, size, and reproductive success of wading bird colonies in Florida was studied. Based on indirect evidence of distribution and turnover rates in relation to jet training routes (<500 ft AGL) and military operations areas, there was no demonstrated effect of military activity on colony establishment or size on a statewide basis. Reproductive activity (including nest success, nestling survival, nestling mortality, and nesting chronology) was independent of F-16 overflights, but was related to ecological factors including location and physical characteristics of the colony, and climatology.

Blaxter, J.H.S., J.A.B. Gray, and E.J. Denton. 1981. Sound and startle responses in herring shoals. J. Mar. Biol. Assoc. U.K. 61:851-869.

Startle responses of shoaling herring (Clupea harengus) to various well-defined sound stimuli were investigated. A sound consisting of only one cycle of a sine wave was as effective a stimulus as a sound of the same amplitude lasting many cycles. The variability of response to a given stimulus was small. If a wave train took several cycles to reach its maximum amplitude, the threshold was raised considerably. If measured as pressures, the amplitudes of single-cycle stimuli needed for constant responses were almost independent of the duration of the stimuli (range tested: 2-40 ms). Observations on the directions in which fish moved shortly after a stimulus showed that most fish moved away from the source of sound, although the proportions of fish making "errors" did vary between different experimental arrangements. Most responses started with Mauthner-type bends; these were usually away from the source. With respect to the directionality of responses, single-cycle stimuli were as effective as those lasting many cycles. The authors conclude that herring can receive, in a transient sound, sufficient information to determine the amplitude of the sound and the general direction from which it comes, and they argue that, while the directional sense demands information on particle velocities and presssure, responses are triggered by pressure alone.

Blaxter, J.H.S., and D.E. Hoss. 1981. Startle response in herring: the effect of sound stimulus frequency, size of fish and selective interference with the acoustico-lateralis system. J. Marine Biol. Assoc. U.K. 61:871-879.

Herring (Clupea harengus) show a characteristic "startle" response when subjected to vibrational stimuli from a diaphragm in the wall of their tank. Threshold measurements on fish, 2.8-17 cm total length, tested at frequencies from 70 to 200 Hz showed that the response was elicited by sound pressures between 2 and 18 Pa, the most sensitive fish were in the length range from 8-11 cm. Intermediate-sized fish of 12-13 cm also responded to sounds from a loudspeaker in air above the tank; the mean threshold was about 5 Pa. The stimulus was thought to be the sound pressure rather than particle velocity component of the stimulus, with the gas-filled pro-otic bulla acting as part of the pressure detecting system. Pretreatment of fish by shock exposure increases of 4 atm to burst the bulla membrane increased the threshold about 10 times.

Bogert, C.M. 1960. The influence of sound on the behavior of amphibians and reptiles. Pages 137-320 in W.E. Lanyon and W.N. Tavolga, eds. Animal sounds and communications. Am. Inst. Biol. Sci., Washington, DC.

Literature on the influence of sound on the behavior of amphibians and reptiles is discussed in detail. Topics include mechanisms of sound production, hearing, and behavior related to calls of various species of amphibians and reptiles. Sonograms of several species are included.

Bond, J. 1971. Noise: its effect on the physiology and behavior of animals. Sci. Rev. 9(4):1-10.

This paper reviews 21 research studies on the effect of noise, primarily sonic booms and aircraft, on behavior and productive capacity of farm-raised animals. Most of the studies were initiated to obtain reliable data on which to base decisions on damage claims supposedly resulting from supersonic aircraft flying over animal installations. The author stresses planned studies to provide some solid answers about the effects of sonic booms on farm-raised animals, and on wildlife; a number of incidents have been recorded that indicate the effects may be more detrimental to some wildlife than to some domestic animals.

Bond, J., T.S. Rumsey, J.R. Menear, L.I. Colber, D. Kern, and B.T. Weinland. 1974. Effects of simulated sonic booms on eating patterns, feed intake, and behavioral activity of ponies and beef cattle. Pages 170-175 in Proceedings of the International Livestock Environment Symposium, University of Nebraska, Lincoln. Am. Soc. Agric. Eng., St. Joseph, MI.

Eight ponies, 2 open cows, 6 cows with calves, and 24 steers were used in a series of trials to study the effects of simulated sonic booms (overpressure of 200 N/m^2) on eating patterns, feed intake, and behavioral activity. All animals clearly showed a startle response after each boom. Eating patterns and feed intake were not affected by sonic booms.

Bond, J., C.F. Winchester, L.E. Campbell, and J.C. Webb. 1963. Effects of loud sounds on the physiology and behavior of swine. U.S. Dept. Agric., USDA-ARS Tech. Bull. No. 1280.

Pigs, boars, and sows were exposed to reproduced aircraft noise and other loud sounds to determine possible harmful effects on reproduction. The animals were exposed to sound frequencies varying from 100-120 dB. The conception rate of sows exposed to the recorded sounds was similar to that of unexposed sows. The number of pigs farrowed and the number of survivors were not influenced by exposure of the parents to loud sound during mating, or exposure of sows to reproduced sounds at 120 dB for 12 hours daily beginning 3 days before farrowing and continuing until their piglets were weaned.

Bondello, M.C. 1976. The effects of high-intensity motorcycle sounds on the acoustical sensitivity of the desert iguana, Dipsosaurus dorsalis. M.A. Thesis. California State University, Fullerton. 37 pp.

Acoustical sensitivity of desert iguana (Dipsosaurus dorsalis) was lost after exposure to high-intensity motorcycle sounds of 114 dBA for 1 and 10 hours. Animals tested immediately after sound exposure had a greater loss of activity than animals tested 7 days later. Permanent sensitivity losses were noted in lizards exposed for both 1 and 10 hours. Animals exposed for 10 hours suffered the severest permanent losses. The destructive sound dose was less than 1 hour, and the time in which loss was totally recovered exceeded 7 days.

Borg, E. 1978. Peripheral vasoconstriction in the rat in response to sound. I. Dependence on stimulus duration. Acta Otolaryngol. 85: 153-157.

Arterial pulsations in the tail of the rat were recorded in response to noise bursts at 80 dB SPL with durations from 1 minute to several hours. Response during continuous stimulation habituated slowly and the time to reach normalization was more than 15 minutes.

Borg, E. 1978. Peripheral vasoconstriction in the rat in response to sound. II. Dependence on rate of change of sound level. Acta Otolaryngol. 85:332-335.

Arterial pulsations in the tail of the rat were measured in response to 80-dB SPL noise. Sound bursts of 4 s with rise times of 1, 10, or 100 ms were equally efficient in eliciting vasoconstrictions. If the rise time was longer (1 s), the vasoconstriction was significantly smaller.

Borg, E. 1978. Peripheral vasoconstriction in the rat in response to sound. III. Dependence on pause characteristics in continuous noise. Acta Otolaryngol. 85:155-159.

The offset of a noise (80 dB SPL) was a weak stimulus for vasoconstriction in the tail of the rat. A vasoconstriction was regularly elicited by onset of sound after the end of a pause. The vasoconstriction was independent of pause duration varying from 10 ms to 100 s. For shorter pauses, the vasoconstriction was smaller. The results were discussed in relation to decay of sensation and partial masking effects.

Borg, E. 1979. Physiological aspects of the effects of sound on man and animals. Acta Otolaryngol. Suppl. 360:80-85.

This paper reviews some of the short-term and long-term physiological effects of sound on nonauditory body functions in man and laboratory rodents. Short-term effects depend closely on the acoustic properties of sound. Habituation is rapid for steady signals and slow for intermittent signals. Spontaneously hypertensive rats were more susceptible to inner ear injuries than normotensive rats. The potential role of individual variability in noise-induced hearing loss is discussed.

Borg, E. 1981. Physiological and pathogenic effects of sound. Acta Otolaryngol. Suppl. 381:7-68.

The acoustic influence of sound on various somatic functions (excluding the auditory system proper) and the possible effects on health, especially with regard to conditions in occupational life, were reviewed. While the literature survey showed a large number of contradictory ideas and information, there was little doubt that cardiac and vascular, as well as hormonal, somatic, and somato-sensory systems can be influenced by short unexpected bursts of sound. In some animal experiments, extremely intermittent sound pressure (85-105 dB SPL), day and night, caused a moderate rise of blood pressure. Sound gave pronounced short duration reactions in rats, but no chronic effects were observed during prolonged exposure. Species differences with respect to physiological reactions to sound exist and point towards a higher sensitivity in animals than humans. Any possible harmful effects of sound may be more related to information content of the sound--information pertaining to risky actions or masking significant information--rather than to sound itself.

Boutelier, C. 1968. The sonic bang: its effects on man and animals. Vet. Bull. 38:328. [Abstract.]

The physics of the sonic bang are described with reference to the factors influencing it and to the effects on man of sonic boom experiments carried out in the United States, United Kingdom, and France in 1961-1965. Complaints from farmers have concerned injuries to frightened animals, killing of young by mink and rabbits, suffocation in panic-struck fowls, reduced egg production, and pheasants breaking their eggs; no reactions have been observed in cows. Experiments on army dogs in France are reported in which the effects of the frequency and intensity of the bangs on behavior and cardiac rate were investigated. The author concludes that the effects of sonic bangs should be thoroughly studied in each domesticated species.

Brattstrom, B.H., and M.C. Bondello. 1983. Effects of off-road vehicle noise on desert vertebrates. Pages 167-206 in R.H. Webb and H.G. Wilshore, eds. Environmental effects of off-road vehicles. Impacts and management in arid regions. Springer-Verlag, New York.

This study involved measurement of natural and mechanized sound sources in the California desert and the effects of off-road vehicle (ORV) noise on the behavior and hearing physiology of three species of desert vertebrates: Mohave fringed-toed sand lizard (*Uma scoparia*), desert kangaroo rat (*Dipodomys deserti*), and Couch's spadefoot toad (*Scaphiopus couchi*). Because critical environmental sounds are often of relatively low intensity (snake crawls and owl swoops), sensitive hearing acuity is essential to the survival of these desert vertebrates. As a result of natural selection, they have evolved the ability to hear low-intensity, low-frequency sounds. The high forces required to operate heavy equipment and drive ORV's through sand and rock generate high-intensity sounds concentrated in the lower frequencies. These sounds carry farthest in desert air and are known to penetrate distances exceeding 4 km. Animals from quiet, protected sand dunes (*Uma* and *Dipodomys*) suffered immediate loss of hearing when exposed to ORV sounds (95 dBA). Recovery of hearing in *Dipodomys* was gradual and took several weeks, during which time the demonstrated auditory abilities of prey animals to detect predator approach dropped below levels requisite for survival. Recorded motorcycle sounds of intermediate intensity (95 dBA) elicited emergence of spadefoot toads, a potentially deleterious impact on the toad population. Emergence during the wrong season severely stresses toads. They become dehydrated from lack of water, their fat stores are depleted, potential prey base may be low or non-existent, and their reproductive cycle is changed. The authors recommend that

ORV designated areas should be located away from all undisturbed desert habitats, critical habitats, and ranges of threatened, endangered, or otherwise protected habitats.

Bromley, M. 1985. Wildlife management implications of petroleum exploration and development in wildland environments. General Tech. Rep. INT-191. U.S. Dep. Agric., Forest Serv., Intermountain Res. Sta., Ogden, Utah. 42 pp.

Potential environmental disruptions caused by petroleum exploration, development, and production are discussed, including effects of these disruptions on wildlife behavior, habitat, and populations. Strategies are considered for minimizing and mitigating these adverse effects. The section on impacts includes a detailed outline/index referring to an annotated bibliography; general noise and aircraft noise are included in the index. Major wildlife groups discussed are ungulates, carnivores, waterfowl, raptors, waterbirds, and songbirds.

Broucek, J., M. Kovalcikova, and K. Kovalcik. 1983. The effect of noise on the biochemical characteristics of blood in dairy cows. Zivoc. Vyr. 28(4):261-267.

The physiological responses of 80 dairy cows to sound were studied. In the first trial, the sound of a tractor engine (97 dB) significantly increased glucose concentration and leucocyte counts and markedly reduced the level of hemoglobin in the blood. In another trial, pure-tone sound (1,000 Hz, 110 dB) increased circulating glucose, nonesterified fatty acids, and creatinin, and decreased the level of hemoglobin, with a slight decrease in thyroxin in plasma.

Brown, C.H. 1980. Primate directional hearing in noisy habitats. Am. Soc. Zool. 20(4):790. [Abstract.]

Minimum audible angles were behaviorally determined in macaque (*Macaca* spp.) monkeys. Testing was conducted in an anechoic chamber with synthetic stimuli that spectrally mimicked representative macaque vocalizations. Localization was tested in quiet and in the presence of a broad-band masker that simulated habitat noise. Results showed that the optimal signal structure for localization was dependent on the ambient noise condition; narrow-band signals were most accurately localized. The data suggested that in noisy habitats, narrow bands (heightening the signal-to-noise ratio) may be strategic for the design of signals favoring localization, as well as detection of sound. The acoustic structure of the position marking and rallying calls of some primates may reflect these factors.

Bullock, T.H., D.P. Domning, and R.C. Best. 1980. Evoked brain potentials demonstrate hearing in a manatee (Trichechus inunguis). J. Mamm. 61:130-133.

Brain responses to arbitrary sounds were studied in a young manatee by the method of transcranial-averaged, evoked-potential recordings over the cerebrum. The frequency that gave the greatest response was approximately 3 kHz, but the maximum effectiveness was not sharply defined. Little systematic change in energy was recorded between 300 and 6,000 Hz as monitored by a microphone. Averaged evoked potentials were seen as low as 200 Hz and up to 35 kHz, but not at 40 kHz; possibly, the less effective stimuli were masked by ambient noise and the earphones were severely attenuating the higher frequencies used. Peak sensitivity (3 kHz) was in the range of vocalizations recorded in manatees (2-10 kHz).

Burger, J. 1981. Behavioral responses of herring gulls (Larus argentatus) to aircraft noise. Envir. Pollut. (Ser. A) 24:177-184.

The behavior of nesting and loafing herring gulls (Larus argentatus) was compared when the birds were exposed to supersonic transport, subsonic aircraft, and normal colony noises at Jamaica Bay National Recreational Area near Kennedy International Airport in New York. Colony noises and distant hum of traffic produced an average ambient noise level of 77 dBA; noise levels of jets averaged 91.8 dBA (non-SST) and 108.2 dBA (SST). No effects of subsonic aircraft on nesting gulls were noted. However, when supersonic transports flew over, significantly more nesting gulls flew from their nests, and they engaged in more fights when they landed compared with the other conditions. Many eggs were broken during these fights, and eggs were subsequently eaten by intruders. At the end of the incubation period, mean clutch sizes were lower in dense sections (more potential for fights) of the colony compared with solitary nesting pairs of gulls. For loafing gulls, significantly more birds flushed when planes flew over, compared with immediately before and after such plane noises.

Burger, J. 1983. Jet aircraft noise and bird strikes: why more birds are being hit. Environ. Pollut. (Ser. A) 30:143-152.

Birds are attracted to airports because of the absence of predators and the presence of roosting, bathing, drinking, and feeding areas. About 75%-90% of all civil aircraft strikes occur near airports, mostly while planes are taking off and landing. Birds are struck because they do not perceive the threat, or cannot avoid the plane once they perceive it. The number of bird strikes has increased with the faster speeds of aircraft. The noise levels of departing and landing aircraft were examined as a function of type of aircraft. In general, the wide-bodied aircraft (Boeing 747, L1011, DC10) were significantly quieter than the old-type, narrow-bodied aircraft (Boeing 707, 727). Noise levels varied when approaching planes were different distances from the test site. Noise levels did not rise significantly higher than predeparture levels until the planes were between 600 and 800 m from the test site; the planes traversed this distance in an average of 9-14 s. For landing planes, the narrow-bodied planes were significantly louder than the wide-bodied planes at touchdown, only 600 m from the test site. Wide-bodied planes had significantly more bird strikes than the narrow-bodied aircraft. These results indicate that birds have less warning of an approaching wide-bodied aircraft than they have for narrow-bodied aircraft. The bird's behavior of facing and flying into the wind (in the same direction that the airplane is moving) decreases the flight speed of the bird and increases the risk of a bird strike (particularly for the wide-bodied aircraft).

Busnel, R.G., and D. Molin. 1978. Preliminary results of the effects of noise on gestating female mice and their pups. Pages 209-247 in J.L. Fletcher and R.G. Busnel, eds. Effects of noise on wildlife. Academic Press, New York.

The effect of noise alone and noise plus two other stressors on reproduction of mice was studied. Direct effects of noise and indirect effects of stress reactions of the females were examined. Noise exposure consisted of 1 hour of recorded subway noise (approximately 105 dB SPL) played four times daily. No significant differences were found in mothers' weights, number of young born, number of young surviving weaning, or sex ratios of young. However, noise-exposed mice experienced a longer time interval between litters and lower weight gain of young, compared to the controls.

Busnel, R.G., and J.L. Briot. 1980. Wildlife and airfield noise in France. Pages 621-631 in J.V. Tobias, G. Jansen, and W.D. Ward, eds. Proceedings of the Third International Congress on Noise as a Public Health Problem. Am. Speech-Language-Hearing Assoc., Rockville, MD.

Observations of birds and mammals were made at several airports in France, and data also were collected from systematic hunts to reduce avian populations that were potential sources for collisions with aircraft. From 1973-1977, populations of gulls (Larus spp.), pigeons (Columba spp.), raptors, and crows (Corvus spp.) appeared to increase at the airports. Likewise, collisions between birds and aircraft increased during the same period. Analysis of the data revealed that observed fluctuations in animal populations were associated more with bioclimatic conditions than with the effects of noise.

Buwalda, R.J.A., and J. van der Steen. 1979. The sensitivity of the cod sacculus to directional and non-directional sound stimuli. Comp. Biochem. Physiol. 64:455-604.

Results of recording saccular (labyrinth of the inner ear) microphone responses to underwater sound stimuli in cod (Gadus morhua) are presented. Stimuli with pressure to velocity ratios of -50 to +10 dB far field value were produced by standing wave manipulation. In high-velocity conditions a cosine dependence of microphonic levels on sound direction was found, compatible with a vector detector function for left and right sacculus. High pressure abolished this directional sensitivity. At 122 Hz and pressure/velocity ratios of -12 dB, pressure and velocity were equally effective, resulting in a microphonic null response at a phase lead of velocity by 90 degrees. The demonstrated directional sensitivity of various saccular receptor fields might, in principle, be a basis for horizontal as well as vertical directional hearing.

Calef, G.W., E.A. DeBock, and G.M. Lortie. 1976. The reaction of barren-ground caribou to aircraft. Arct. 29(4):201-212.

The responses of barren-ground caribou (Rangifer arcticus) to fixed-wing aircraft and helicopters were observed in the northern Yukon and Alaska. Escape or strong panic reactions were noted in 65%-75% of all groups observed from the fixed-wing aircraft at altitudes of up to 500 ft, but in only 10%-25% of the caribou observed from the helicopter. Caribou at river crossings reacted more to aircraft than traveling or feeding animals, and resting animals reacted least. Size of group, terrain, or vegetation type did not appear to affect the caribou's response to aircraft. Reactions during the calving season were stronger than during spring and fall migrations. The authors recommend flying at a minimum aircraft altitude of 500 ft during summer and fall migrations, and 1,000 ft at other times. Following the herd with a helicopter elicited extreme panic reactions, potentially dangerous to individuals in the herd.

Campbell, H. 1969. The effects of temperature on the auditory sensitivity of lizards. Physiol. Zool. 42:183-210.

The effects of temperature on the auditory sensitivity of selected species of lizards of the families Iguanidae, Gekkonidae, Anguidae, and Teidae were examined using tone pulses and click stimuli. The temperature of the maximum auditory sensitivity varied as a function of the natural thermal preference for each species. Sensitivity decreased as temperature was varied either above or below the range of preferred temperatures for normal activity. The lowest and highest temperatures at which a response could be elicited varied with the upper and lower thermal tolerance levels for the particular species. All species examined were most sensitive to sounds between 900-3,500 Hz. This frequency range was found to contain much potential information of ecological significance to the species (e.g., presence of predators, movement of insects). Average sensitivity loss of 10-20 dB/10 °C was found in the region of maximum sensitivity.

Capranica, R.R., and A.J.M. Moffat. 1975. Selectivity of the peripheral auditory system of spadefoot toads (Scaphiopus couchi) for sounds of biological significance. J. Comp. Physiol. 100:231-249.

The spadefoot toad (Scaphiopus couchi) is a primitive anuran that inhabits the arid regions of the southwestern U.S. The vocal repertoire of this toad consists of a mating call and a release call; the calls are distinct and differ in trill rate. Reception of airborne sound is achieved by means of a poorly differentiated region of skin on the head which serves as an eardrum.

Most modern anurans have three types of auditory nerve fibers, but spadefoot toads have only two types: a low-frequency-sensitive (50-750 group and a high-frequency-sensitive (850-1,550 Hz) group.

Casady, R.B., and R.P. Lehmann. 1967. Response of farm animals to sonic booms. Studies at Edwards Air Force Base, June 6-30, 1966. Interim Rep., U.S. Dept. Agric., Agric. Res. Div., Beltsville, MD. 8 pp.

The effects of sonic booms on farm animal behavior and reproduction were investigated at Edwards Air Force Base in California. All animals had experienced sonic booms prior to the study. Observed behavioral reactions of animals to the booms were minimal except for avian species. Reactions were more pronounced from low-flying subsonic aircraft noise than from booms.

Chapman, C.J., and O. Sand. 1974. Field studies of hearing in two species of flatfish Pleuronectes platessa (L.) and Limanda limanda (L.) (Family Pleuronectidae). Comp. Biochem. Physiol. 47A:371-385.

Field measurements of hearing in two flatfishes (Pleuronectes platessa, Limanda limanda) demonstrated that they are sensitive to sounds in the frequency range from 30 to 250 Hz with greatest sensitivity around 110-160 Hz. Both species were sensitive to particle motion. The sound pressure thresholds decreased by several decibels in the presence of an air-filled balloon, simulating a swim bladder. The mechanism of hearing in flatfish is discussed, and the authors suggest that the otolith organs in the labyrinth are the acoustic receptors. Comparison between hearing data for flatfish and for the cod (Gadus morhua) suggests that differences in performance may be attributed to the accessary role of the swimbladder in the hearing of cod.

Chesser, R.K., R.S. Caldwell, and M.J. Harvey. 1975. Effects of noise on feral populations of Mus musculus. Physiol. Zool. 48(4): 323-325.

House mice (Mus musculus) were captured from two similar fields--one rural and one located near an airport. The only apparent difference between the two fields was the presence or absence of low-flying aircraft. Airport field noise levels varied from 80-120 dB, while rural field levels varied from 80-85 dB. Mice from the airport field had significantly larger adrenal glands. To determine if noise was a causative factor, mice collected from the rural field were exposed to recorded jet noise at 105 dB in the laboratory. These mice also developed significantly larger adrenals than control mice.

Clark, C.W. 1976. Acoustic communication and behavior of southern right whales, Eubalaena australis. Natl. Geogr. Res. Rep. 17:897-907.

The sounds made by southern right whales (Eubalaena australis) are not random, but are intimately related to the social context and activity of the animals. A resting whale does not call very often but sometimes makes long moans while exhaling through its nostrils. A swimming whale that is alone and seeking other whales makes "up-calls." Excited whales make high calls, hybrid calls, pulsive calls, flipper slaps, and loud forceful blow sounds. Not yet determined is whether some variable in the contact call encodes for the identity of the caller, and whether the more complex associations among variables in the sounds from active whale encode for some subtle parameters of the social context.

Coombs, S., and A.N. Popper. 1982. Structure and function of the auditory system in the clown knifefish, Notopterus chitala. J. Exp. Biol. 97:225-239.

Hearing sensitivity and the anatomy of the auditory system in the clown knifefish (Notopterus chitala) were studied using behavioral techniques and scanning electron microscopy. While many structural features of the inner ear were similar to those found in other teleost species, the saccular endorgan in the knifefish was unusual in having three discrete epithelial regions. These regions could be distinguished from one another by regional differences in portions of the otolith overlaying them, by hair-cell orientation patterns, and by their position relative to the swimbladder. The knifefish was found to be able to detect sounds from 100 to 1,000 Hz, and best sensitivity occurred at 500 Hz, where the mean threshold was -30 dB (1 microbar). For frequencies from 300 to 700 Hz, there was substantial variation in threshold values and indications of a bimodal distribution of thresholds. One hypothesis that may tie the ultrastructural and behavioral results together is that the ear of the knifefish is anatomically and functionally differentiated to mediate independent detection of two sound properties: changes in pressure and particle motion.

Copukuh, M.A., and A.H. Lebedea. 1985. title? J. 1? No. 9:45-1? [English summary.]

The audiograms of three fish species (Pleurogrammus monopterygius, Liopsetta obscura, and Pleuronectes stellatus) without swim bladders were determined under laboratory conditions by the method of conditioned reflex. The fishes perceived signals within a frequency of 300-500 Hz with maximum sensitivity of 63-125 Hz. The optimum range of discovering signals in noise was 20-125 Hz, where acoustic maximum exceeded spectral noise of 17-23 dB.

Cottereau, P. 1978. Effect of sonic boom from aircraft on wildlife and animal husbandry. Pages 63-79 in J.L. Fletcher and R.G. Busnel, eds. Effects of noise on wildlife. Academic Press, New York.

The introduction of commercial and military supersonic aircraft has raised the question of whether sonic booms should be considered as severe environmental pollution, with adverse effects on humans, animals, and structures. Much of the present knowledge is based on occasional booms, many of which have resulted in complaints and claims. Although probably not always legitimate, these complaints indicate that concern has developed about the effects of this new environmental factor, and this concern should stimulate intensified research. However, only a few investigations under real or simulated conditions have been undertaken so far to try and elucidate the possible effects of sonic booms; these studies are reviewed, and the physical aspects of sonic booms are discussed. Behavioral observations of domestic animals appear to indicate that sonic booms and subsonic low-level flight noise evoke startle reactions, but have little effect on the animals' overall behavior. Animals also appear to adapt to the disturbances. Avian species seem to be more affected than mammals; adverse effects on reproduction may result from sonic boom exposures of colonially nesting birds. The greatest research need is for critical observations of the response of aggregations of various social mammals and birds to sonic booms of measured overpressure and duration. Cooperative research in this area, with a large participation of biologists, is recommended.

Cox, M., P.H. Rogers, A.N. Popper, W.M. Saidel, and R.R. Fay. 1986. Frequency regionalization in the fish ear. J. Acoust. Soc. Am. 79(Suppl.1):S80. [Abstract.]

The exact mechanism for frequency discrimination by bony fishes is unknown; however, results of another experimental study suggested the existence of frequency regionalization on the saccular macula in the ears of codfish (Gadus morhua). Frequency regionalization is similar to the place mechanisms in the cochlea in that different frequencies stimulate different areas of the saccular and lagenar maculae. In this study, goldfish (Carassius auratus) were subjected to a single-frequency tone, about 140-150 dB above threshold, for 2 hours in order to damage areas sensitive to that frequency. During this exposure, the fish was constrained inside a waveguide with controllable acoustic pressure and particle velocity characteristics. The extent of regionalization on the maculae was determined based on electrophysiologically measured degradation of frequency tuning and hair cell damage found in examination under a scanning electron microscope. In addition, the separate effects of acoustic pressure and particle velocity on frequency regionalization were compared.

D'Arms, E., and D.R. Griffin. 1972. Balloonists' reports of sounds audible to migrating birds. Auk 89:269-279.

The 19th century balloonists often noted that commonly occurring sounds were audible, at least under some conditions, up to altitudes of 3,000 m or more. The cackling of geese, the singing of frogs and insects, and the sound of wind blowing through woods were commonly heard up to roughly 1,000 m. Breaking waves and the sounds of running streams were frequently noted. Thus, migrating birds may well be able to hear characteristic sounds from the ground or water beneath them. A bird might be able to detect and correct for its wind drift, even without visual cues from the surface of the earth, by localizing sound sources and comparing its actual progress with its heading. Early balloonists studied ground echoes of shouts and other loud sounds generated in the balloon, and they sometimes noted much louder and clearer echoes from lakes or streams than fields or woods; a sonic altimeter was later developed for use from airplanes. This suggests the possibility that nocturnal migrants could employ a crude form of echolocation, provided that their flight calls are loud enough to generate audible echoes from the surface. No data are available on the degree to which sounds originating at the surface (or echoes from the surface) differ in acoustic spectrum depending upon the direction from which they are heard. If breaking waves or other sounds generated by the wind sound different according to their direction, this could theoretically provide directional information to a migrating bird.

Dade County Aviation Department. 1977. Site 14 and the Endangered Species Act: an assessment of the interaction of the Florida Everglades kite, its critical habitat and the operation of an airport at Site 14. Dade Co. Aviation Dep , Miami, Florida. Unpubl. Rep. 57 pp.

Site 14, located in north Dade County, Florida, was proposed as the relocation site for the Everglades Jetport Training Facility in 1975. At that time, no endangered or threatened species were identified as present on or near the site. In 1976 and 1977, a small colony of Everglades kites (Rostrhamus sociabilis), an endangered species, nested on a willow (Salix spp.) island 3 miles west of the proposed runway. A study was undertaken to ascertain the possible effects of the jetport facility on nearby kite populations, including an assessment of habitat and foraging and soaring behavior. In addition, three airports in South America that are in close proximity to marshes with kite populations were visited. Results of the study indicated that (1) the area under the approaches to the proposed runway at Site 14 was composed of less than 25% typical kite foraging habitat, (2) kites are nomadic in their foraging habits and do not aggregate in large numbers in any one foraging area, (3) foraging flights of kites were under 100-200 ft elevation, (4) high-altitude soaring by kites during the nonbreeding season was infrequent and of relatively short duration, (5) kites observed under the approach path to a runway of a nearby airport were oblivious to frequent jet traffic, and (6) kites observed at the South American airports appeared to be tolerant to the jet traffic, and there were no reported aircraft strikes of kites. The report concludes that the construction and operation of an airport at Site 14, with adequate land-use and development restrictions or safeguards, was not expected to jeopardize the continued existence of the Everglades kite or result in the destruction or adverse modification of the critical habitat as defined for the Endangered Species Act of 1973.

Dancer, A., and Franke, R. 1972. Influence of pressure rise time of an N shock wave, simulating the sonic boom, on the cochlear and acoustically evoked potentials of the guinea pig. Natl. Tech. Inf. Serv., Springfield, VA. 45 pp. [In French.]

The influence of pressure rise times of forward and backward fronts of N shock waves simulating sonic booms on the cochlear and acoustically evoked potentials of the guinea pig were investigated. Experimental results have shown that at a given boom intensity, the front duration has an influence on the maxima amplitudes of cochlear and acoustically evoked potentials and, therefore, on the transmitted sound intensity. The authors concluded that to characterize a sonic boom, it is necessary to determine not only its amplitude (or intensity), but also its forward and backward fronts.

Dancer, A., R. Franke, G. Evrard, B. Adam, and L. Oudin. 1973. Pressure variation effects on the guinea pig middle ear under impulse sound excitation. Natl. Tech. Inf. Serv., Springfield, VA. Rep. No. N75-21002/1st. 33 pp. [In French.]

Displacements of the eardrum/cochlea in the guinea pig under shock wave and ordnance sounds excitation were studied by middle ear pressure variation measurements. The time to maximum displacement was measured together with the effect of sound intensity and duration of the first positive wave phase. The maximum elongation was dependent only on sound intensity, and its value was approximately 15 microns/mbar. For a specific waveform, a frequency analysis was performed that showed attenuation of frequencies below 5 kHz and a resonance at 6.7 kHz.

Dancer, A., R. Franke, G. Evrard, C. Zeller, and P. Massard. 1972. Determination of lesion threshold in the guinea pig auditory area due to sonic boom. Natl. Tech. Inf. Serv., Springfield, VA. Rep. No. N73-27966/3. 64 pp. [In French.]

The effects of the sonic boom intensity (20-50 mbar, 300 msec) and repetition frequency on the guinea pig auditory sensation areas, especially on eardrum and middle ear, were investigated. The histological study of the inner ear and audiometric tests have determined the lesion threshold of sonic booms at 30 mbar. A slight auditory perception loss was noticed after exposure to a sonic boom, and slight lesions of eardrum after exposure to frequent booms.

Dancer, A., R. Franke, and H.J. Pfeifer. 1974. Laser interferometric studies of the guinea pig eardrums displacement under various acoustic excitations: pure sounds, N waves, shock waves, etc. Natl. Tech. Inf. Serv., Springfield, VA. 43 pp.

The guinea pig eardrum displacement at umbilicus level under various acoustic stimulation was studied by laser interferometry. Pure sound induced displacements of order 2.4 micron/mbar for frequencies between 30 and 1,000 Hz. At 10 kHz, these displacements are reduced by a factor of 10. High amplitude pressure variations induced a reduction of the ration displacement/overpressure from 4 mbar upwards. This ration increased for underpressures in excess of 2 mbar. Recordings were performed following N wave stimulations of the sonic boom type and double positive pulses. The umbilicus closely followed pressure variations. The overpressure duration has a major influence on umbilicus displacement for values above and below 1-8 ms, where displacement increases as a function of duration.

Dancer, A., M. Schaffar, M. Hartmann, P. Cottereau, and J. Pin. 1973. Effects of sonic bangs on the behavior of fish (*Lebistes reticulatus* or guppy). Institut Franco-Allemand de Recherches, St. Louis, France. 29 pp. [English abstract.]

A comparison of the effect of sonic booms on guppies (*Lebistes reticulatus*) revealed that fish subjected to sonic booms produced by a generator exhibited only observed reactions of short duration (0.5 s), which appeared for intensities higher than 1 mbar.

Davies, D.H., J.P.A. Lochner, and E.D. Smith. 19__. Preliminary investigations on the hearing of sharks. Ocean. Res. Inst., Durban, South Africa. Invest. Rep. 7. 10 pp.

A number of sharks (*Carcharinus obsurus*, *C. maculipinnis*, *C. leucas*, and *Sphyrna lewini*) were conditioned to respond to pure tones and octave bands of random noise, and their thresholds of hearing were determined for those stimuli. Sharks responded to pure tones of 50-7,000 Hz and to octave bands with frequencies varying from 64-3,000 Hz. Results suggested that sharks are not able to discriminate between frequencies and that recognition of signals is based on the amplitude versus time characteristics. Apparently, sharks can accurately determine the direction of a sound source.

Davis, P. 1967. Ravens' response to sonic bang. Brit. Birds 60:370-371.

The author noted the response of a population of ravens (*Corvus corax*) to a sonic boom in central Wales. Three or four ravens were idling in the up-currents over a high rock spur between two streams. When the silence was shattered by a "very loud sonic bang as a jet aircraft passed overhead," the author heard ravens calling agitatedly and saw small groups flying from all directions and converging over the crest of the spur. In about 5 minutes, 62-70 ravens were present. They were flapping, soaring, and chasing each other, with a great deal of noise, and often settled briefly on the rocks. Ravens from at least 2 or 3 miles around may have been involved. Within 10 minutes, they started to disperse again, and the calling died down considerably. About 30 ravens were still soaring over the hill when the author left the area, an hour after the boom.

Dooling, R. 1978. Behavior and psychophysics of hearing in birds. J. Acoust. Soc. Am. 64(Suppl.1):S4. [Abstract.]

Psychophysical investigations of hearing in a number of avian species over the last decade have added significantly to the knowledge of hearing capability characteristics of this vertebrate group. Behavioral measures of absolute auditory sensitivity in a wide variety of bird species show a region of maximum sensitivity between 1 and 5 kHz, with a rapid decrease in sensitivity at higher frequencies. On the basis of this general measure, birds fall between two other major vertebrate groups: reptiles and mammals. Discrimination and masking data from birds include measures of frequency, intensity, and duration difference limens: critical ratios, critical bands, and psychophysical tuning curves. Data also are available on temporal summation, temporal resolving power, and temporary threshold shift from noise exposure. Taken together, these data suggest that, in the region of 1-5 kHz, birds show a level of hearing sensitivity similar in most respects to that found for the most sensitive members of the class Mammalia, with avian performance clearly inferior above and below this range of frequencies. Possible exceptions to this general picture include the echolocating oilbird (Steatornis caripensis) and growing evidence that pigeons (Columba spp.) are sensitive to infrasound at moderate intensity levels. The relation among critical ratio, critical band, and intensity difference limen measures in the parakeet (Melopsittarus sp.) is similar to that described for the human, but the pattern of masking as a function of frequency is dramatically different from that observed in mammals. Examples of a correspondence between hearing sensitivity and vocalizations can be demonstrated in a number of species.

Dooling, R.J., and M.H. Searcy. 1981. Amplitude modulation thresholds for the parakeet (Melopsittacus undulatus). J. Comp. Physiol. 143:383-388.

Parakeets were tested for the ability to detect sinusoidal amplitude modulation of broad-band noise. Instrumental avoidance conditioning and a psychophysical modified method of limits procedure were used to measure the threshold for detecting amplitude modulation at 10 modulation frequencies between 2 and 2.048 Hz. Below about 40 Hz, modulation threshold is independent of modulation rate and noise level. Above 40 Hz, modulation threshold decreases with modulation frequency at the rate of 3 dB/octave. These results are somewhat different from amplitude modulation functions in humans, which suggests different degrees of temporal resolving power in birds and humans. Thresholds for changes in modulation rate are 1-2 orders of magnitude higher than pure tone frequency difference thresholds.

Dufour, P.A. 1980. Effects of noise on wildlife and other animals: review of research since 1971. U.S. Environmental Protection Agency, EPA 550/9-80-100. 97 pp.

This report reviews significant studies completed since EPA issued its first report concerning noise effects on wildlife in 1971. The report covers laboratory animals, domestic animals, and wildlife and is presented in four major categories of noise effects: auditory physiological, masking, nonauditory physiological, and behavioral.

Dunnet, G.M. 1977. Observations on the effects of low-flying aircraft at seabird colonies on the coast of Aberdeenshire, Scotland. Biol. Conserv. 12:55-63.

The greatly increased use of helicopters and fixed-wing aircraft to support the exploration and exploitation of oilfields in the North Sea gives rise to concern about possible disturbance to seabirds breeding in the flight paths. The observations reported in this paper were made at a mixed colony of fulmars (Fulmarus glacialis), shags (Phalacrocorax aristotelis), herring gulls (Larus argentatus), kittiwakes (Rissa tridactyla), guillemots (Uria aalge), razorbills (Alca torda), and puffins (Fratercula artica) breeding on the Buchan Cliffs about 40 km north of Aberdeen, on 2 days during egg-laying and early nestling stages of the breeding season. The birds in attendance at nests or nesting ledges were counted before and after the passage of aircraft, and general observations were made when the planes were overhead. The number of identifiable nests with 0, 1, or 2 adults was noted because disturbance might be most sensitively detected by the departure of nonincubating, brooding adults. No evidence was found to suggest that aircraft flying at heights of about 100 m above the cliff-top affected the attendance of incubating and brooding birds, and there was only a slight indication that a few of the "second adults" at kittiwake nests may have flown off. Groups of kittiwakes resting on nearby cliffs or on the sea did take to the air in response to the planes, but they also did so frequently in the course of the day with no obvious cause. The author stressed that these findings cannot be extrapolated to other species of seabirds or to different conditions.

Edwards, R.G., A.B. Broderson, R.W. Barbour, D.F. McCoy, and C.W. Johnson. 1979. Assessment of the environmental compatibility of differing helicopter noise certification standards. U.S. Department of Transportation, Washington, DC. 58 pp.

To evaluate the impact of relaxed noise emission standards for helicopters restricted to remote regions, areas along the gulf coast of Louisiana and Texas (identified as those areas in the U.S. characterized by the "heaviest of helicopter activity") were visited and environmental noise measurements made for miscellaneous helicopter flyovers and for activity adjacent to heliports. Questionnaires were sent to wildlife refuge directors, Forest Service employees, and National park superintendents in States having the highest helicopter densities. In addition, responses of several species of wildlife to helicopter noise levels were briefly studied at the Aransas National Wildlife Refuge in Texas. Results showed that an average of 10 flyovers/hr produced a 1-hr energy-average sound level (leq) of 54.5 dBA, a level 2.5 dBA above ambient. An average of 34 events/hr adjacent to heliports produced a 1-hr leq of 63.1 dBA, which was 13.3 dBA above ambient. If emission levels were increased by 10 dBA, projected leq (24) values of 57.0 and 71.2 dBA resulted for the flyover and heliport conditions, respectively. Sixty-four percent of those responding (272) to the questionnaire stated that they had not observed a problem from helicopter noise. Of those that had observed such a problem, interference with "rest and relaxation" and with "wildlife" were most frequently mentioned. The responses of different wildlife species to helicopter noise varied considerably. For example, Canada geese (Branta canadensis) and snow geese (Chen caerulescens) appeared to be more disturbed by helicopter noise than turkey vultures (Cathartes aura), pronghorns (Antilocapra americana), coyotes (Canis latrans), and raptors.

Ehret, G. 1977. Comparative psychoacoustics: perspectives of peripheral sound analysis in mammals. Naturwissenchaften 64:461-470.

Psychophysical data on hearing in man, domestic cats, guinea pigs, house mice (Mus musculus), dolphins (Tursiops truncatus), and horsehoe bats (Rhinolophus ferrumequinum) are summarized. Data are correlated to the anatomy and physiology of the ear. Common mechanisms of sound transfer and analysis in the acoustic system, with emphasis on the auditory periphery, are discussed.

Ellis, D.H. 1981. Responses of raptorial birds to low-level military jets and sonic booms. Results of the 1980-1981 Joint USAF-USFWS Study. Natl. Tech. Inf. Serv., Springfield, VA. NTIS ADA108-778. 59 pp.

Data on the likely effects of low-level jets and sonic booms on nesting peregrine falcons (Falco peregrinus) and other raptors were gathered at aeries in Arizona. Responses to extremely frequent and nearby jet aircraft were often minimal and never associated with reproductive failure. Nesting success and site reoccupancy rates were high for all aeries. No significant changes in heart rate response were noted. The birds observed were noticeably alarmed by the noise stimuli (82-114 dBA), but the negative responses were brief and never productivity limiting.

Ellis, N.D., I.B. Rushwald, and H.S. Ribner. 1975. A one-man portable sonic boom simulator. J. Sound and Vibration 40(1):41-50.

A portable sonic boom simulator was developed for field tests on wildlife. Previous portable simulators were mobile only by truck or trailer; the present device weighs 24.4 pounds (including peripherals) and is easily carried by one person. It consists of a shock tube charged by a compressed air bottle, coupled to an exponential horn. A low-pass acoustic filter is mounted in the horn, and serves to increase the ultra-short rise time of the shock waves (about 10 μs) to a value more nearly characteristic of sonic booms (about 0.5 ms). The simulated sonic booms mimic the loudness of typical sonic booms and have comparable overpressure and rise times. Calibration of the effective loudness is by subjective comparison with idealized standard sonic booms (N-waves). The calibration is carried out in the recently developed UTIAS loudspeaker-driven sonic boom booth. The loudspeakers accurately reproduce the signatures, which have been tape recorded; the signatures are judged against the N-waves for equal loudness by an observer in the booth. The outcome is expressed as equivalent sonic boom overpressure, as a function of shock-tube driver pressure and observer position relative to the portable simulator.

Ely, F., and W.E. Peterson. 1941. Factors involved in the ejection of milk. J. Dairy Sci. 14(3):211-223.

The literature on the factors involved in the ejection of milk by dairy cows is reviewed. The authors also report the results of experiments to determine the relationship between the nervous system and milk ejection, and the effects of fright (caused by exploding paper bags) and adrenalin on this relationship. Fright caused by an unusual event could reflexly stimulate the natural production of adrenalin, which results in cessation of milk ejection.

Espmark, Y. 1972. Behaviour reactions of reindeer exposed to sonic booms. Deer 2:800-802.

Reindeer (Rangifer tarandus) in an enclosure were exposed to 36 sonic booms (varying from 35-702 Pa) for 3 days. The animals had experienced occasional exposure to sonic booms. No clear differences in reaction were seen between low and high boom strengths. Moderate reactions were found irrespective of boom level. Common reactions were slight startle responses, raising of head, pricking the ears, and scenting the air. Panic reactions or extensive changes in behavior of individual animals were not observed.

Espmark, Y., L. Falt, and B. Falt. 1974. Behavioral responses in cattle and sheep exposed to sonic booms and low-altitude subsonic flight noise. Vet. Rec. 94(6):106-113.

Twenty cattle and 18 sheep were exposed to 28 sonic booms (80-370 Pa) and 10 low-altitude (50-200 m AGL) subsonic flights during 4 days. Noise levels varied from 75-109 dBA. No adverse effects were observed and behavioral reactions were considered minimal. Both species were less disturbed near the end of the test period, indicating the animals had adapted to the disturbance. Adaption probably also masked some of the dose-response relationships that were more obvious in cattle than in sheep. The authors suggested that observed reactions (e.g., backward jumping) may be more dangerous for tied-up animals, and that the effects of disturbances might be more severe for animals under certain physiological conditions, such as gestation.

Ewbank, R. 1977. The effects of sonic booms on farm animals. Vet. Annual 17:296-306.

The nature of aircraft noises and the sonic boom is described. The possible effects of sonic booms on farm livestock and other animals are reviewed. Brief discussions are included on cattle, sheep, horses, pigs, mink, and poultry. The author recommends further investigations on the effect of sonic booms on dairy cows, laying poultry, and horses.

Fay, R.R. 1974. Sound reception and processing in the carp: saccular potentials. Comp. Biochem. Physiol. 49A:29-42.

Saccular potentials to sound simulation were recorded from two locations in the endolymphatic system of the carp (Cyprinus carpio). The frequency response function recorded from the sacculus is essentially identical with the behavioral function for the goldfish (Carassius auratus), confirming that the sacculus is the primary acoustic detector of the ostariophysine ear. Measurements of the nonlinearities in the saccular potentials illustrate the complex organization of the saccular macula, and a possible mechanism for signal-to-noise improvement and frequency analyzing capability, which is independent of a cochlear-like spatial analysis, is suggested.

Fay, R., and A. Feng. 1983. Mechanisms for directional hearing among nonmammalian vertebrates. J. Acoust. Soc. Am. 73(Suppl. 1):S18. [Abstract.]

Adaptations for directional hearing among nonmammalian vertebrates are diverse, and include morphological and physiological mechanisms at both peripheral and central levels, as well as behavioral strategies. While some of these mechanisms (such as interaural differences in time and spectrum based on head size) operate to some extent among all terrestrial vertebrates, the nonmammals show several additional special features. Fishes can locate sound in space and use directional filtering to improve signal-to-noise ratios, based on the directional characteristics of hair cells themselves, and on the patterns of hair cell orientation both within and between receptor organs (saccule, lagena, and possibly the utricle). In addition, fishes may code the phase relations between particle acceleration and the sound pressure waveforms to solve 180-degree ambiguity problems. The terrestrial nonmammals are faced with similar problems in sound localization, including a relatively small interaural distance and generally poor high-frequency hearing. However, anurans and birds localize sounds well. The anuran ear shows a complex, frequency-dependent directionality; the wide coupling of the two middle cavities via the mouth lead to acoustic interactions that enhance interaural time and intensity differences. This type of mechanism is thought to operate in some birds as well, particularly at low frequencies. Some owls may use more "mammalian" mechanisms for azimuthal localization in addition to a vertical asymmetry in ear position that gives rise to interaural cues for elevation.

Fay, R.R., W.A. Ahroon, and A.A. Orawski. 1978. Auditory masking patterns in the goldfish (Carassius auratus): psychophysical tuning curves. J. Exper. Biol. 74:83-100.

The masking effects of tones on the detection auditory signals were studied in goldfish (Carassius auratus) using the psychophysical tuning-curve paradigm. For signals below 350 Hz, masking is an inverse function of the frequency separation between masker and signal, a finding consistent with previous masking studies on fishes, birds, and mammals. For signals above 350 Hz, masking peaks occur both in the 350-Hz region and at the frequency of the signal. Quantitative comparisons with recent neural tuning curves for goldfish saccular neurones suggest frequency selectivity below 350 Hz, but by a neural analysis of temporal patterns above this range.

Fell, R.D., C.J. Ellis, and D.R. Griffith. 1976. Thyroid responses to acoustic stimulation. Environ. Res. 12:208-213.

Male and female rats were subjected to noise stress (95 dBA) presented in 15-min intervals, 8 hours per day for 12 weeks. Body weights and thyroid I-131 uptake values were recorded. Relative body weight gain rates were significantly reduced. Thyroid I-131 uptake values were low for both sexes, and a positive correlation between the time of decreased iodine uptake and suppressed weight gain rates was noted.

Fleischner, T.L., and S. Weisberg. 1986. Effects of jet aircraft activity on bald eagles in the vicinity of Bellingham International Airport. Unpublished Report, DEVCO Aviation Consultants, Bellingham, WA. 12 pp.

In 1985, Pacific Southwest Airlines (PSA) began jet aircraft flights into Bellingham International Airport, Whatcom County, Washington. A biological assessment was undertaken to (1) determine the status of the bald eagle (Haliaeetus leucocephalus) within the area near the airport, (2) evaluate eagle habitat in the area, (3) evaluate any effects of jet flights on eagle behavior and population dynamics, and (4) suggest recommendations for mitigation of impact, if appropriate. The project area contains critical bald eagle habitat, and bald eagles are residents throughout the year. During field observations, bald eagles reacted to the presence of aircraft in the study area during 12% of the eagle-aircraft observations. A differential eagle response to aircraft types was observed; helicopters and small jets had the greatest effect on bald eagles. Eagles reacted to PSA jets 11% of the time, to propeller airplanes 2% of the time, to helicopters 40% of the time, and to small jet aircraft 55% of the time. Observed reactions of eagles to PSA jets consisted of turning the head to look at the jet (5% of the observations), and flying from a perch site (5%). Eagle reactions to PSA jets were twice as frequent when the eagle-jet distance was one-half mile or less. Present level of jet flights appeared to have minor effects on bald eagles within the project area. Disturbances such as repeated flight from perches and interrupted eagle interactions would have a negative effect on bald eagles if they occurred more frequently. The authors made several recommendations to minimize the impact of jet aircraft, including location of flight paths to avoid eagle habitat and minimizing the number of jet flights per day.

Fletcher, J.L. 1980. Effects of noise on wildlife: a review of relevant literature 1971-1978. Pages 611-620 in J.V. Tobias, G. Jansen, and W.D. Ward, eds. Proceedings of the Third International Congress on Noise as a Public Health Problem. Am. Speech-Language-Hearing Assoc., Rockville, MD.

The author reviewed the scientific literature published since 1971 on the effects of noise on wildlife and other animals. Relatively few new studies were found. These studies are briefly discussed. Further research needed to answer critical questions about the effects of noise on animals includes studies of (1) individual species, as individual animals and in social groups (herds, flocks, etc.), that examine the acoustic nature (frequency, intensity, temporal patterns, etc.) of critical events (mating, territoriality, alarm, nurture, etc.); (2) the spectrum of environmental sound and of an animal's hearing sensitivity; (3) effects of noise on a declining animal population, regardless of the cause of the population decline; (4) stressor effects of noise with other stresses on an animal; (5) long- and short-term noise effects; and (6) possible critical sound propagation in the field.

Fletcher, J.L., M.J. Harvey, and J.W. Blackwell. 1971. Effects of noise on wildlife and other animals. U.S. Environmental Protection Agency, Rept. NTID 300.5. 74 pp.

Literature for the period 1950-1971 on the effects of noise on animals was reviewed. Studies on laboratory and domestic animals and wildlife, including mammals, birds, fish, and insects, are summarized. Only the relevant and readily obtainable reports from the foreign literature are included. Suspected effects of noise on wildlife, both direct effects and interference with social signals, are discussed. The authors stated that "few if any of the reported or suggested effects of noise on animals would benefit the animal or increase his chances for survival; on the other hand, some of them might possibly lead to his death or decrease his chances for survival." The authors recommended research programs devoted to the study of effects of noise on wildlife existing in their native habitat under normal conditions, concurrent with careful examination of physiological and other physical and chemical effects of noise on animals. An important consideration in planning research should be the frequencies to be investigated, as well as the sound levels. Frequencies that are inaudible to humans (ultrasound) are well within the audible range of many animal species.

Franke, R., C. Lursat, and G. Evrard. 1971. Auditory loss and recuperation of guinea pigs after exposure to a sonic boom, sonic boom produced by the ISL generator. Natl. Tech. Inf. Serv., Springfield, VA. Rep. No. N72-31097. 25 pp.

The auditory loss threshold provoked by the TSS Concorde sonic boom N-type shock wave was evaluated from guinea pig auditory reflexes. An audiometric method based on the Preyer reflect threshold measurement was used. The experimental results showed that a slight and temporary effect is noticeable for a 40 m/bar pressure wave (40 times more intense than the sonic boom).

Frazier, A.R. 1972. Noise survey, F-105 overflights, Wichita Mountains Wildlife Refuge and vicinity, Fort Sill, OK. U.S. Dept. Commerce, Natl. Tech. Inf. Serv., Springfield, VA. 62 pp.

In 1972, The U.S. Air Force (USAF) proposed using an area near Fort Sill, Oklahoma, for F-105 overflights. The range has been operational since 1957 and is used to fire a variety of weapons, including Honest John Missiles. The projected number of single F-105 passes over the target area would be a maximum of 248 per day, during 1000-1300 h and 1500 h. During use of the range, aircraft would pass a fixed ground location every 30-45 seconds. The range would not be used for supersonic flight. The proposed flights would be

5,000-12,000 ft AGL at 300-400 knots over the Wichita Mountains Wildlife Refuge (WMWR), and 100-1,000 ft AGL at 450 knots above the weapons range. On 29 August 1972, the USAF Environmental Health Laboratory conducted a noise survey to quantify environmental noise levels produced by F-105 flights over two sites at the adjacent WMWR at two towns, 1.5 and 3.0 miles from the flight line. Several different instruments, including sound level recorders, octave band analyzers, tape recorders, calibraters, and microphones, were used to record the noise level data at the four sites. The maximum noise level measured at these sites was below 90 dBA. Effects of the flyovers on wildlife were not specifically evaluated, but general observations of buffalo (Bison bison) near the noise measurement equipment indicated that the animals "appeared oblivious" to the aircraft noise and continued grazing throughout all aircraft passes. An area of concern identified in the survey was that the flyover noise may cause classroom distractions at the nearby Job Corps Center on the WMWR. The range of Preferred Speech Interference Levels (PSIL) produced by the F-105 overflights was in the same range of PSIL's produced by power lawn mowers cutting grass near the Center's buildings. The report states that architectural/engineering solutions can be used to compensate for the effects of the F-105 overflights on noise levels of the Center if severe problems develop. Generally, any adverse effects on the environment are expected to be minimal, and serious interference with present or future land uses is not expected.

Friedman, M., S.O. Byers, and A.E. Brown. 1967. Plasma lipid responses of rats and rabbits to an auditory stimulus. Am. J. Physiol. 212:1174-1178.

Rats exposed to a continuous sound stimulus at 102 dB and an intermittent sound at 114 dB showed marked elevation and prolongation of clearing of postprandial plasma triglyceride for approximately 21 days. The abnormality could be corrected with epinephrine. Ten weeks later the test animals showed higher blood cholesterol and more intense atherosclerosis than control animals.

Gamble, M.R. 1982. Sound and its significance for laboratory animals. Biol. Rev. 57:395-421.

The author reviews studies on the effects of noise on laboratory animals, including studies on the ability of rodents to assess sound. Many of the studies indicated that rats and mice can develop seizures when exposed to loud sounds, or become more susceptible to other sounds later in life. Studies on guinea pigs and cats indicated that hearing damage was governed by the duration as well as the intensity of the sound and was irreversible.

Gold, A. 1973. Energy expenditure in animal locomotion. Sci. 181:275-276.

A wide variety of data on energy expended by animals in running, flying, or swimming can be accounted for by the hypothesis that all animals require the same quantity of energy to carry a unit of their own body mass one "step." For running locomotion this is approximately 0.0004 calories per gram per step.

Gould, E. 1983. Mechanisms of mammalian auditory communication. Pages 265-342 in J.F. Eisenberg and D.G. Kleiman, eds. Advances in the study of mammalian behavior. Am. Soc. Mamm. Special Publ. 7.

Sound production and auditory communication in a variety of mammals are discussed. Mammalian vocalizations range in frequency from the horse's roar of 50 to 100 Hz up to 150 kHz in some bats. High-frequency sounds are extremely directional and attenuate quickly with distance. Low-frequency sounds attenuate slowly with distance and are relatively omnidirectional. The transmission properties of a vocalization depend on environmental factors (temperature, humidity, landscape, vegetation). Range of vocal signal is influenced by intensity of the source, level of background noise, rates of signal degredation, and the perceptual abilities of the receiver.

Gourevitch, G. 1983. The localization and lateralization of sound by land mammals. J. Acoust. Soc. Am. 73(Suppl. 1):S17-18. [Abstract.]

During the past few years, research on directional hearing in land mammals branched out considerably. For the first time, physical measurements were made of interaural time differences between the ears of animals. Further measurements of interaural intensities were also determined. Localization acuity was examined in previously untested species, among which were the largest terrestrial mammal (elephant, Elephas sp.) and one of the smallest (kangaroo rat, Dopodomys sp.). Extensive investigations were conducted on sound localization, and on binaural sensitivity for putative directional cues in nonhuman primates. The localization of different macaque (Macaca sp.) vocalizations tending to occur in different social contexts was also investigated. Altogether, this work indicates that (1) in comparison to other terrestrial mammals, man's directional hearing remains foremost; (2) in a number of instances, localization is not as accurate as might be expected on the basis of head size; (3) the sensitivity of the binaural system does not necessarily increase to compensate for weaker interaural differences in a small headed animal, and may be less than in humans; and (4) in lower primates, localization may have an important communicative role in addition to that of orientation.

Griffin, D.R., and C.D. Hopkins. 1974. Sounds audible to migrating birds. Anim. Behav. 22:672-678.

Sound levels of frog choruses were measured in eastern New York State at altitudes of up to several hundred meters. Bullfrog (Rana catesbeina) choruses from small ponds often could be recorded by a radio microphone up to 500 m, and on an especially favorable night with light winds, they were clearly audible even at 965 m at about 20 dB SPL in the 1.5 to 2.5 kHz frequency band. Sound travels upward much farther and more predictably than along the surface. Many natural sounds, including those from frogs, insects, whitecaps, and perhaps wind-blown vegetation, arise from large areas and therefore act as extended sources. The intensities of such sounds decrease with altitude more slowly than expected from the inverse square law. Natural sound fields provide migrating birds with a potential source of information about the kind of land or water below them, and their progress over acoustic landmarks could inform them about wind velocity. Because atmospheric absorption increases with frequency, several hundred meters of air act as a low-pass filter, so that altitude could be estimated from the relative reduction of higher frequencies in a familiar sound.

Griffin, D.R., J.J.G. McCue, and A.D. Grinnel. 1963. The resistance of bats to jamming. J. Exp. Zool. 152:229-250.

The resistance of long-eared bats (Plecotus townsendii) to jamming was analyzed by obstacle-avoidance tests in noise of various frequency bands. Jamming was significantly more effective in 10- to 90-kHz noise than in 10- to 50-kHz noise, but raising the upper limit of the noise spectrum to 120 kHz (with considerable but unmeasured energy above 120 kHz) had no discernible effects. The fundamental frequencies of the bat's orientation sounds sweep from 45 to 25 kHz. Directional discrimination results partly from acoustic properties of the external ears, and partly from a type of binaural interaction between nerve impulses from the two cochleas.

Gunn, W.W.H., and J.A. Livingston, eds. 1974. Disturbance to birds by gas compressor noise simulators, aircraft, and human activity in the Mackenzie Valley and the North Slope, 1972. Arct. Gas Biol. Rep. Ser. 14. 280 pp.

This report contains eight studies on the effects of disturbance to waterfowl, seabirds, and terrestrial breeding birds in the Mackenzie Valley and North Slope of Alaska and Canada. Float-plane disturbance over 3 days decreased the waterfowl population on a small (0.08 mi^2) experimental lake by 60%; numbers remained stable on a small control lake until a low-passing bald eagle (Haliaeetus leucocephalus) caused 45-50 birds to leave the lake. Numbers of waterfowl on larger lakes (0.10-0.62 mi^2) declined slightly during the disturbance, but population data were inconclusive because of problems obtaining consistent counts. Low-flying helicopter disturbance and human activity did not affect the population density of lapland longspurs (Calcarius lapponicus), but lower number of addled eggs, hatching success, and fledging success, and higher nest abandonment and premature disappearance of nestlings occurred on the disturbed site compared to the control site. In colonies of black brant (Branta bernicla), common eiders (Somateria mollissima), glaucaus gulls (Larus hyperboreus), and Arctic terns (Sterna paradisaea), human presence appeared to affect incubating behavior of birds more than fixed-wing aircraft or helicopters. Helicopters were more disturbing to birds than fixed-wing aircraft. Indications were that disturbance as a whole may be detrimental to the nesting success of black brant and Arctic terns. Nonbreeding birds appeared to be more disturbed by people and by both types of aircraft than were nesting birds. Molting waterfowl were driven from land by helicopter disturbance 100 yards from shore at altitudes of 100-750 ft AGL. Surf scoters (Melanitta perspicillata) appeared to be more sensitive to the disturbances than oldsquaws (Clangula hyemalis). No detectable numbers of waterfowl were driven away from the area by the disturbance. Resting snow geese (Chen caerulescens) were disturbed by a Cessna 185 at altitudes varying from 300-10,000 ft AGL. Geese tended to flush at greater distances when the aircraft was under 1,000 ft AGL. After severe disturbance, flock sizes were reduced with a consequent increase in the number of flocks. Geese were driven from a 50-mi^2 area by "hazing" with a Cessna 185. The authors recommended curtailing aircraft flights over the premigratory staging areas between 15 August and 30 September. The reports emphasized the need for additional research with more detailed study designs to fully evaluate the effect of disturbance on birds in the Mackenzie Valley and North Slope.

Ha, S.J. 1985. Evidence of temporary hearing loss (temporary threshold shift) in fish subjected to laboratory ambient noise. Proc. Pennsylvania Acad. Sci. 59:78. [Abstract.]

During a study of masking effects on the hearing of the lane snapper (Lutjanus synagris), fish held in certain aquaria had consistently higher than normal thresholds to pure tones, when tested later in a low noise apparatus. Comparison of laboratory aquaria showed that the only difference in aquaria was the presence of conventional air stones (in the aquaria holding the less sensitive fish) used to release compressed air to oxygenate and mix the water. Hearing tests on two groups of fish, held with and without airstone air release, showed significant differences in hearing sensitivity.

Harbers, L.H., D.R. Ames, A.B. Davis, and M.B. Ahmed. 1975. Digestive responses of sheep to auditory stimuli. J. Anim. Sci. 41:654-658.

The effect of three types of noise (at 75 and 100 dB) on metabolism in sheep was studied. Animals ate less when exposed to sound exceeding background levels. Intermittent noise increased water intake and metabolizable energy, and improved apparent nutrient digestibilities.

Harrison, J.M. 1984. The functional analysis of auditory discrimination. J. Acoust. Soc. Am. 75:1845-1854.

Mammals have evolved the ability to acquire auditory discriminations. Sound levels above about 90 dB are likely to be aversive and are associated with a number of behaviors such as retreat from the sound source, freezing, or a strong startle response. Sound levels below about 90 dB usually create much less aversive behavior. This paper reviews experiments that were directed at showing that auditory discriminations are most rapidly acquired when natural features are incorporated into the experiments. The experiments were also directed at discovering the underlying characteristics of the discriminative ability. When animals were trained to discriminate the position of a sound source in which natural features were incorporated into the experiment, the discrimination was acquired in one trial. Manipulation of the natural features suggested that one-trial acquisition depends upon (1) stimulus novelty--the effect of reinforcement is stronger in the presence of novel than familiar stimuli, and (2) specific behavioral effect of reinforcement--the effect of reinforcing a response in the presence of a novel auditory stimulus is to increase the strength of approaching and manipulating the sound source.

Hawkins, A.D., and A.D.F. Johnstone. 1978. The hearing of the Atlantic salmon, *Salmo salar*. J. Fish Biol. 13:655-673.

The hearing of the Atlantic salmon (*Salmo salar*) was studied by means of a cardiac conditioning technique. The minimum sound level to which the fish responded was determined for a range of pure tones, both in the sea and in the laboratory. The fish responded only to low-frequency tones (below 380 Hz); particle motion, rather than sound pressure, proved to be the relevant stimulus. The sensitivity of the fish to sound was not affected by the level of sea noise under natural conditions, but hearing is likely to be masked by ambient noise in a turbulent river. Sound measurements made in the River Dee, near Aberdeen, Scotland, led to the conclusion that salmon are unlikely to detect sounds originating in air, but that they are sensitive to substrate-borne sounds. Compared with carp (*Cyprinis carpio*) and cod (*Gadus morhua*), the hearing of the salmon is poor, and more like that of the perch (*Perca fluviatilis*) and the plaice (*Pleuronectes platessa*).

Heaton, M.B. 1972. Prenatal auditory discrimination in the wood duck (*Aix sponsa*). Anim. Behav. 20:421-424.

On the day prior to hatching, wood duck (*Aix sponsa*) embryos were tested for their response to a taped maternal call of a wood duck or a mallard (*Anas platyrhynchos*) at acoustic levels of 80-82 dB. Sixty-five percent of the embryos receiving the species-specific call increased bill-clapping during stimulus presentation, and 75% of the embryos receiving the mallard call decreased bill-clapping. During each call, the heart rates of embryos increased significantly. Because the wood duck's postnatal behavior with respect to the species-specific call was inconsistent, the demonstrated prenatal specificity may require some sort of supportive auditory input, perhaps similar to that occurring in the natural situation, to maintain and carry over for functional significance into postnatal life.

Hecock, R., and K. Rhoads. 1979. Noise, aircraft, wildlife, and people: a bibliographic review. Final report. Coop. Wildl. Res. Unit, Oklahoma State University, Stillwater. 21 pp.

This annotated bibliography concerning the effects of noise on wildlife and humans, with emphasis on noise from jet airplanes, includes brief abstracts of 18 papers on animals, 26 papers on humans, and 14 Environmental Impact Statements. The report does not include a discussion or summary section.

Heffner, H. 1977. Hearing and sound localization in the kangaroo rat (Dipodomys merriami). J. Acoust. Soc. Am. 61(Suppl. 1):S59. [Abstract.]

Hearing thresholds were determined for two kangaroo rats using a two-choice procedure. The rats successfully responded to frequencies varying from 50 Hz to 64 kHz. The two-choice procedure was then used to determine the ability of the animals to localize single clicks. The results of these tests indicate, first, that the kangaroo rat possesses good high- and low-frequency hearing and, second, that it can locate the source of a brief sound.

Heffner, H., and B. Masterton. 1980. Hearing in glires: domestic rabbit, cotton rat, feral house mouse, and kangaroo rat. J. Acoust. Soc. Am. 68:1584-1599.

Behavioral audiograms were determined for four species of glires: one lagomorph [domestic rabbit (Oryctolagus cuniculus)] and three feral rodents [cotton rat (Sigmodon hispidus), house mouse (Mus musculus, and kangaroo rat (Dipodomys merriami)]. Considerable variation in hearing ability was found among the four species, with low-frequency hearing limits varying over 5.5 octaves, from 50 Hz (kangaroo rat) to 2,300 Hz (feral mouse), and high-frequency hearing limits varying from 49 kHz (rabbit) to 90 kHz (feral mouse). Comparison of the characteristics of each audiogram with the audiograms of other animals in the same order, cohort, and class provided further evidence for the validity of two relationships (1) interaural distance is strongly and inversely correlated with high-frequency hearing ability, and (2) good high-frequency hearing is apparently incompatible with good low-frequency hearing in most, if not all, land mammals. Furthermore, cotton rats and feral mice possess the ability to perform frequency discriminations even at high-frequency levels. Finally, kangaroo rats are not unusual in their ability to localize brief sounds, indicating that these animals have not compromised this ability in their acquisition of their unusual low-frequency sensitivity.

Heffner, R., H. Heffner, and N. Stichman. 1979. Hearing in the elephant (Elephas maximus). J. Acoust. Soc. Am. 65(Suppl. 1):S55. [Abstract.]

The auditory sensitivity of a 7-year-old female Indian elephant (Elephas maximus) was determined using a two-choice procedure. The elephant was sensitive to low-frequency tones and could hear as low as 16 Hz at 65 dB. The frequency of best hearing was 1 kHz, at which the animal's threshold was 8 dB. However, the elephant was insensitive to high-frequency tones and was unable to hear above 12 kHz, at which frequency its threshold was 72 dB. The high-frequency hearing ability of the elephant is the poorest of any mammal yet tested, and the failure of the elephant to hear much above 10 kHz demonstrates that the inverse correlation between head size (i.e., interaural distance) and high-frequency hearing ability is valid even for the largest of terrestrial mammals. Furthermore, this finding indicates that humans can no longer be considered unique among mammals for their inability to hear above 20 kHZ. Instead, the upper limit of human hearing is a consequence of our relatively large head size and not the result of any special adaptation for the reception of speech sounds.

Heffner, R.S., and H.E. Heffner. 1985. Hearing in mammals: the least weasel. J. Mamm. 66:745-755.

Audiograms were obtained for two least weasels (Mustela nivalis) using behavioral methods. The hearing range of the least weasel for intensities of 60 dB SPL extends from 51 Hz to 60.5 kHz, with a region of best hearing extending from 1 kHz to 16 kHz. The least weasel appears to be similar in its hearing to other members of the order Carnivora for which data are available. The high-frequency hearing ability of the least weasel lends additional support to the relationship between functional interaural distance and high-frequency hearing, whereas its sensitivity to low frequencies in the absence of obvious morphological specialization of the middle ear makes the least weasel unusual among the small mammals.

Heinemann, J.M. 1969. Effects of sonic booms on the hatchability of chicken eggs and other studies of aircraft-generated noise effects on animals. In Proceedings of the Symposium on Extra-auditory Effects on Audible Sound. AAAS annual meeting, Boston, Mass.

At White Sands Missile Range, New Mexico, 3,415 chicken eggs were exposed during incubation to over 600 sonic booms produced by supersonic aircraft. When compared to controls, no significant differences in hatchability or teratogenic effects were noted. Of the chickens raised to sexual maturity, weight gain, onset of egg laying, and egg production were similar between the two groups.

Hepworth, J.L. 1966. Hematology of Sigmodon hispidus: average parameters compared with those under induced stresses. Ph.D. Thesis. Oklahoma State University, Stillwater. 81 pp.

Blood samples were obtained from stressed and nonstressed wild cotton rats (Sigmodon hispidus). Stressors included cold weather, food insufficiency, crowding, lack of cover and continuous light, and continuous noise. Sigmodon reflected stressful environmental conditions with changes in the hemogram. The author suggests that both high density and lack of cover are major population hazards.

Herman, L.M., and W.R. Arbeit. 1971. Auditory frequency discrimination from 1-36 kHz in Tursiops truncatus. Pages 79-87 in Proceedings of the Eighth Annual Conference on Biological Sonar and Diving Mammals. Biol. Sonar Lab., Fremont, CA.

This paper provides results of an initial study of auditory frequency discrimination in the Atlantic bottlenose dolphin (Tursiops truncatus), over a frequency range from 1-36 kHz at modulation rates of 1 and 2 Hz. Considerably reduced threshold values occurred at the 2-Hz rate compared to the 1-Hz rate. The data suggested that the bottlenose dolphin has exceptionally low frequency discrimination thresholds, about 6-8 times below those reported for the seal (Phoca sp.).

Higgins, T.H. 1974. The response of songbirds to the seismic compression waves preceding sonic booms. Natl. Tech. Inf. Serv., Springfield, VA. FAA-RD-74-78. 28 pp.

During 1973-74, the Federal Aviation Administration (FAA) studied the effects of sonic booms on the environment during routine U.S. Air Force supersonic acceptance test flights of F-111 jets, southwest of Fort Worth, Texas. This paper reports the behavioral response of songbirds in an oak (<u>Quercus</u> spp.) woodlot to F-111 flyovers. The jets flew over the observation area at 20,000-41,000 ft at Mach 1.0-1.55; peak overpressure values at the site were measured at 0.55-3.25 psf (mean=1.15). The continuous songs of birds were completely silenced 4-8 seconds before arrival of the audible sonic boom. Further study disclosed that this response of songbirds coincided with the arrival of the seismic signal propagated through the ground and preceding the sonic boom shock wave by 4-8 seconds. This difference in the arrival times of the audible sonic boom and the seismic signal was caused by the greater velocity of the seismic compression wave signal transmitted through the dense earth medium ahead of the audible atmospheric sonic boom shock wave that was advancing over the earth's surface at a speed equal to the ground speed of the supersonic aircraft. This helps explain phenomena described in historical tales and literature regarding a "hush or stillness falling over" an area preceding some remarkable event, such as a volcanic eruption, explosion, or earthquake at sea generating a tidal wave. When the sonic booms were audible, the songbirds uttered "raucaus discordant cries" for a few seconds. Within 10 seconds after the audible boom, the songbirds were singing their normal songs.

Hoffman, H.S., and J.L. Searle. 1968. Acoustic and temporal factors in the evaluation of startle. J. Acoust. Soc. Am. 43:269-282.

When startle was repeatedly evoked in rats, the response decreased in amplitude, but adaptation was slow and not complete after 675 stimulus presentations. Startle reactions were amplified when testing occurred in a background of steady noise. A weak signal could inhibit the reaction to a subsequently presented intense signal. The authors concluded that weak signals can activate the neural mechanisms responsible for the startle reaction.

Hrubes, V., and V. Benes. 1965. The influence of repeated noise stress on rats. Acta Biol. Med. German. 15:592-596. [English summary.]

The effect of repeated noise stress (95 dB) on rats was studied. Increased secretion of catecholamines in the urine, increase in free fatty acids in the plasma, increased weight of the adrenal glands, and inhibition of growth of treated rats were noted when compared to untreated controls.

Hubbard, H.H., D.J. Maglieri, and D.G. Stephens. 1986. Sonic-boom research--selected bibliography with annotation. NASA TM-87685. 40 pp.

This report includes citations of selected documents that represent the state-of-the-art technology in each of the following subject areas: prediction, measurement, and minimization of steady-flight sonic booms; prediction and measurement of accelerating-flight sonic booms; sonic-boom propagation; the effects of sonic booms on people, communities, structures, mammals, birds, and terrain; and sonic-boom simulator technology. Documents are listed in chronological order in each section of the paper, with key documents and associated annotation listed first. The sources are given along with acquisition numbers, when available, to expedite the acquisition of copies of the documents.

Huse, S.H. 1983. Relative and absolute pitch perception by birds. J. Acoust. Soc. Am. 74(Suppl.1):S80. [Abstract.]

European starlings (Sternus vulgaris) were trained to discriminate a class of rule-based, four-tone, ascending pitch patterns from a comparable class of descending pitch patterns. A series of tests examined the birds' ability to maintain the discrimination under various transformations of the original pitch stimuli. The birds performed well when new shifts in tone height occurred within the original pitch training range, but not when shifts in tone height occurred outside that range. When information about the direction of pitch change was reduced by shortening the patterns, the birds could solve the discrimination on the basis of the first two tones in a pattern, although performance improved as pattern length and, therefore, amount of information increased. The same series of transfers showed that, in producing accurate discrimination, the birds were using pitch cues based on both an absolute and relative perception of pitch.

Hurtubise, F.G., D.H. McKay, and F. Macenko. 1978. Aircraft pollution: noise and other types. Envir. Prot. Serv., Ontario, Canada, Econ. Tech. Rev. Rep. EPS 3-EC-78-13. 33 pp.

This report discusses types of pollution related to aircraft operations, including noise, air, water, and solid waste pollution. The effects of noise on humans are mainly discussed; a short section on wildlife is included. The cost to society in terms of pollutants on human health and on the environment is covered, and methods of dealing with these pollutants are outlined. The discussion is related to the Canadian experience, including the problem and the solution. The federal environmental assessment and review process, which ensures that environmental effects are taken into account early in the planning of federal projects, is described.

Ilichev, V., V. Voronetskii, and T. Golubeva. 1971. The sonar medium of the long-eared owl (Asio otus), and the spectral sensitivity of its auditory nerves. Z. Zhurn 50:1358-1368. (English summary; abstract in Bird-Banding, 1972, 43:65-66.]

A broad spectrum of components was measured in the sonar environment of the long-eared owl (Asio otus). The important components included the sounds of prey (e.g., squeaks and rustle of rodents); calls of nestlings, fledglings, and other adult owls; and nuptial alarm calls. To perceive and locate these sounds (which varied from 0.5 to 11.0 kHz), the owl's hearing has to be selective to distinguish them from natural background noise. The owl's own calls differentiate into four to six frequency components separated by subequal intervals, showing a harmonic character. The spectrum range was 0.3-0.5 kHz for nestlings, 0.3-0.8 kHz for fledglings, and 0.1-0.6 kHz for adults. In the first nerve component of the recorded cochlear potential, the highest sensitivity was in the range of 4-7 kHz; the sounds of prey and fledglings fell within this span, and required the highest aural specialization.

Ishii, H., and K. Yokobori. 1960. Experimental studies on teratogenic activity of noise stimulation. Gunma J. Med. Sci. 9:153-167.

Female mice were exposed to 90, 100, or 110 phons of white noise for 6 hours per day from the 11th through 14th day of pregnancy. Compared with controls, the noise-exposed females had more stillborn and more malformed young as well as smaller embryos. Females exposed to noise had significantly fewer circulating eosinophils.

Isley, T.E., and L.W. Gysel. 1975. Sound-source localization by the red fox. J. Mamm. 56:397-404.

Vocalizations of prey species are sometimes pure-toned calls, which are more difficult to locate than multifrequency calls. Vertebrates do not locate all pure-toned sounds with the same accuracy. In a controlled test, the authors determined how well nine red foxes (Vulpes vulpes) located 13 different frequencies of pure sound, varying from 300 Hz to 34 kHz. Using food as a reward, the foxes were trained to choose the correct location of a 74 (plus or minus 4) decibel (0.0002 dynes/cm^2) sound signal emitted from one of two possible loudspeaker positions. The foxes located the sound source best from 0.9 to 14 kHz (>90% accuracy) with a slight decrease in accuracy at 8.5 kHz (84% accuracy). They had the most difficulty locating the source at 0.3, 0.6, 18, and 34 kHz (<78.1% accuracy). Foxes appear to readily locate a wide range of sound frequencies and may have maximized their chances for locating certain calls that are presumably difficult to locate.

Jackson, J.A., B.J. Schardien, and T.H. McDaniel. 1977. Opportunistic hunting of a marsh hawk on a bombing range. Raptor Res. 11(4):86.

On 25 February 1977, the authors observed a female marsh hawk (Circus cyaneus) hunting within the target range, near the target site, on a U.S. Navy

bombing range in Noxubee County, Mississippi. During each bombing run, approximately one jet per minute bombed the target with a 25-lb practice bomb from about 1,800 ft. The practice bombs exploded with a noise that seemed to the authors about as loud as a 12-gauge shotgun, gave a brief flash, and released a trail of smoke that allowed observers to measure the accuracy of the pilots. The greatest noise associated with the activity was from the jets; approximately 1,500 ft to the side of the target, noise levels varied between 80 and 87 dB. Throughout the bombing, the marsh hawk continued hunting from a height of 15-20 ft--even when a bomb exploded within 200 ft. Between the bombing runs, the marsh hawk hunted over a larger area of the range, but during the bombing, its activities seemed to be focused more on the target area. The authors felt that this marsh hawk was taking small mammals and birds flushed from cover by the bombing.

Janssen, R. 1980. Future scientific activities in effects of noise on animals. Pages 632-637 _in_ J.V. Tobias, G. Jansen, and W.D. Ward, eds. Proceedings of the Third International Congress on Noise as a Public Health Problem. Am. Speech-Language-Hearing Assoc., Rockville, MD.

Future research needed on the effects of noise on animals is discussed, including primary and secondary effects, understanding auditory functions, stress effects, and the need for specific noise criteria. Exposure and response of all species should be quantified to aid the decisionmaker's ability to judge the effects of specific impacts of noise.

Jehl, J.R., and C.F. Cooper, eds. 1980. Potential effects of space shuttle booms on the biota and geology of the California Channel Islands: research reports. Center for Marine Studies, San Diego State University, San Diego, CA. Tech. Rep. 80-1. 246 pp.

A number of field, laboratory, and library investigations were undertaken between 1978-1980 to assess the potential for damage because of concern that the intense sonic booms from the space shuttle might have adverse effects on important biological and physical resources of the Channel Islands. Results of eight studies are included in this report. Topics covered include historic and current disturbances to natural resources on San Miguel Island; status of the peregrine falcon (_Falco peregrinus_), seabirds, and pinnipeds on the Channel Islands; effects of impulse noise and sonic booms on seabirds; and possible physiological effects of space shuttle booms on marine mammals.

The peregrine falcon was a common resident of the Channel Islands during the early 1900's. The decline and eventual disappearance of the population may have been caused by the decline in prey base (murrelets and auklets). Currently, no pairs nest on the islands, but there appears to be adequate prey base to support breeding pairs. A few falcons winter on the islands. Populations of harbor seals (_Phoca vitulina_), northern elephant seals (_Mirounga angustrostris_), California sea lions (_Zalophus californicus_), and northern fur seals (_Callorhinus ursinus_) appear to be increasing on the islands; over 400,000 of these animals are present during the breeding season.

Low-flying helicopters, humans on foot, sonic booms, and loud boat noises were the most disturbing influences to pinnipeds. Humans at roost sites, helicopter overflights, and sonic booms disturbed birds. "Loud" sonic booms (80-89 dBA SEL) elicited more startle reactions in animals than "soft" booms (72-79 dBA). Duration of startle responses to loud booms was shorter than to other disturbances. Among the pinnipeds, harbor seals (Phoca vitulina) were most likely to startle; no serious disturbance was recorded among northern elephant seals. Historical data indicated that the current level of disturbance on San Miguel Island does not measurably affect seabird and pinniped populations. Sonic booms from the space shuttle launches may increase the disturbance level by 10%-20%. Avoiding launches during the pupping season (March-July) is recommended to minimize disturbances. During this season, launches and returns during the noon hours should be avoided to prevent exposure of pups and seabird nestlings to excessive heat. Temporary decreases in hearing sensitivity of marine mammals could occur following the few intense booms caused by launches of the space shuttle directly over the islands, but these are not expected to have negligible population consequences. Careful observations of behavioral effects of space shuttle booms on Channel Island marine mammals, coupled with long-term population monitoring, are recommended.

In noise disturbance tests (shotgun blasts, explosives) at seabird colonies, startled birds that flew from their nests did not knock their eggs from the nests and returned within 30 seconds. Birds were more susceptible to disturbance while they were roosting or courting than during nest-building, incubation, or rearing young, when their tendency to remain at their nest site was strong. In laboratory studies on avian production using white leghorn hens, simulated sonic booms (156.3 dB peak flat) had no effect on oviposition, hatchability, viability, and hatching time, compared to controls. However, chicks subjected to sound stress at 19 days weighed significantly less than the control chicks.

Jehl, J.R., Jr., M.J. White, Jr., and S.I. Bond. 1980. Effects of sound and shock waves on marine vertebrates: an annotated bibliography. U.S. Fish Wildl. Serv., Washington, DC. FWS/OBS-80/02. 6 pp.

This report was intended to introduce resource managers and researchers to the literature about the interaction between underwater acoustic signals and fishes, birds, and mammals. Topics include the effects of various noises and explosives and the use of sound as an attractant or deterrent. Brief abstracts of 25 papers are included.

Jenkins, W., and R.B. Masterton. 1972. Localization of brief sounds by pigeons. J. Acoust. Soc. Am. 61(Suppl. 1):S75-76. [Abstract.]

The ability of pigeons (Columba livia) to localize brief sounds was assessed using a two-choice procedure. Their ability to localize a tone pip varied markedly with frequency. Asymptotic performance levels were above 90% at 125 and 250 Hz, 73% at 500 Hz, 59% at 1 kHz, 60% at 2 kHz, 67% at 4 kHz, and above 90% again at 8 kHz. Therefore, pigeons can localize low and high frequencies well, but middle frequencies (1 and 2 kHz) only with difficulty. Localization in this midrange of frequencies is greatly and immediately enhanced when a narrow band of white noise is substituted for the tone pip.

Jurtshuk, P., Jr., A.S. Whitman, and A.M. Sackler. 1959. Biochemical responses of rats to auditory stress. Sci. 129:1424-1425.

Prolonged, intense auditory stimulation (95-105 dB) caused a marked reduction in glutathione levels in the blood of female rats. The frequency of the response was related inversely to the recovery rate after auditory stimulation. An increase in adrenal weights and ascorbic acid and a decrease in total adrenal cholesterol were noted.

Kiley-Worthington, M. 1984. Animal language? Vocal communication of some ungulates, canids, and felids. Acta Zool. Fennica 171:83-88.

The origin of vocal communication is briefly discussed. The calls of pigs, cattle, horses, dogs, and cats were analyzed, and the types of situations that give rise to the calls were identified. These species have few discrete calls. As a result, the calls can be arranged as a continuum. Different situations elicit the same call, thus, calls do not have specific meanings, rather they act as an analogue system to inform the recipient of the general motivational state of the caller. Communication in social animals helps maintain the group cohesiveness by giving cues to individual identification and next possible action of group members. This in turn must benefit the individual, otherwise it would not be a social animal. Environmental and social controls in many species indicate that vocalizations may not be an appropriate modality for specific messages. This may be gained by using information from other sensory modalities. However, the author emphasized that, to date, little is known concerning the vocalization in most species, and closer analysis may well indicate other more complex systems, such as appears to be the case in recent studies of primates.

King, M.M., and G.W. Workman. 1986. Response of desert bighorn sheep to human harassment: management implications. Trans. N. Am. Wildl. Nat. Resour. Conf. 51:74-85.

Behavioral response of desert bighorn sheep (Ovis canadensis nelsoni) to human disturbance was evaluated in southeastern Utah from 1981 to 1983. Bighorn response was compared between two areas with contrasting disturbance histories. Red Canyon bighorn had been exposed to greater levels of hunting pressure and vehicular traffic than White Canyon bighorn. Eighty-three percent of experimental harassment trials elicited flight responses from Red Canyon bighorn compared to 46% for White Canyon bighorn. Average distance fled as a result of harassment was approximately 2.75 times greater for Red Canyon bighorn than White Canyon bighorn. Group wariness was exhibited at more intense levels by Red Canyon bighorn than White Canyon bighorn when they remained in the presence of harassing stimuli. Activity budgets of unharassed animals differed significantly between areas, particularly with respect to attention and feeding behaviors. Under harassed conditions, Red Canyon bighorn were at attention longer and fed less than White Canyon bighorn. Behavioral responses of desert bighorn to encounters with humans were more severe and thus more energy costly for animals that had been historically exposed to relatively high levels of human disturbance. Wildlife and land managers should include evaluation of past disturbance history in bighorn habitat and plan to minimize potentially harassing human activities in crucial habitat, particularly if bighorn have been exposed to high levels of human disturbance. Further research is needed to determine physiological impacts of human disturbance on desert bighorn sheep. Until such data are available, desert bighorn populations should be managed conservatively.

Klein, D.R. 1971. Reactions of reindeer to obstructions and disturbances. Sci. 173:393-398.

Herders now use snowmobiles instead of reindeer for transportation and herding; however, reindeer are disturbed by the vehicles. If approached too closely, they can panic and become unmanageable. Careless use of snowmobiles during the calving period, when any disturbance can be detrimental to the pregnant females, can result in losses of females or calves. Herders and government officials are concerned that recreational use of snowmobiles will become widespread in Scandinavia and will increasingly disturb the reindeer. Scandinavian experiences with obstructions and disturbances may aid in anticipating problems with caribou, which could occur with increasing developments in wildlands of Canada and Alaska.

Klein, D.R. 1973. The reaction of some northern mammals to aircraft disturbance. Pages 377-383 in 11th Int. Cong. Game Biol. Sept. 3-7, 1973, Stockholm, Sweden. Natl. Swedish Environ. Prot. Board, Stockholm, Sweden.

Increasing use of low-flying aircraft in remote areas occupied by ungulate populations has focused attention on possible effects of aircraft disturbance on wildlife. Such disturbance is most important in treeless terrain where escape cover is lacking. Observations of flight distances and other behavior of caribou (Rangifer tarandus) in Alaska were recorded in relation to altitude and angle of fixed-wing aircraft and helicopter approach, intensity and frequency of sound, and external factors such as weather and terrain. Running and panic occurred when the aircraft were at altitudes of 200 ft or less, and such reactions decreased as flight altitudes increased. Above 500 ft, no panic response was observed. Groups of fewer than 10 animals responded less strongly to the aircraft than larger groups. Groups consisting primarily of cows, calves, and yearlings tended to show a stronger response to the aircraft than groups of bulls. Insufficient observations from the helicopter limited comparison of the two types of aircraft, but general observations indicated that animals showed a stronger reaction to the helicopter than to the fixed-wing aircraft. Incidental observations of other wildlife indicated that wolves (Canis lupus) were least disturbed by aircraft, moose (Alces alces) were less disturbed than caribou, and grizzly bear (Ursus arctos) were the most disturbed of all species observed.

Klump, G.M., and E. Curio. 1983. Why don't spectra of songbirds' vocalization correspond with the sensitivity maxima of their absolute threshold curves? Verh. Dtsh. Zool. Ges. 76:162.

The dominant frequencies in the spectra of a species' calls and song often lie above the frequency range of lowest auditory thresholds. Small birds, like the great tits (Parus major), have difficulties producing low-frequency sounds due to their size. Below a certain frequency threshold a small bird inevitably has to allocate its sound energy into harmonics rather than into the fundamental frequency. In a bird the size of the great tit, this frequency threshold lies at about 2 kHz. Pure-tone whistles can only be produced above this frequency. The main effects on sound propagation are attenuation and environmental noise, both parameters strongly depend on the species' habitat. The "excess attenuation" generally increases with increasing frequency above 2 kHz. The increase is 6 dB/100 m and 15 dB/100 m in the range of 2 to 4 kHz and 4 to 8 kHz, respectively. Measurement of spectra of wind-generated noise in the great tit habitat showed an approximately uniform sound pressure level up to 4 kHz, which decreases above this frequency with about 5 dB/octave. Hence, noise affects frequencies above 4 kHz less severely. Critical ratios of the great tit vary over a range of 22.4 dB to 26.3 dB for frequencies between 0.25 and 8 kHz. Calls designed for long distance communication (e.g., some contact calls) are not optimally tuned to the hearing of the tits. However, environment noise has a strong effect on the best frequency for communication, thus resolving the above discrepancy. In a noisy habitat, most of the great tit's vocalizations, even high frequency calls, are well adapted for long transmission distances.

Knight, T.A. 1974. A review of hearing and song in birds with comments on the significance of song in display. Emu 74:5-8.

The songs of birds are produced by the modulation of air streams in the syrinx of the singing bird. The notes produced may be modulated in amplitude or frequency and serve to carry information. The range of frequency over which birds produce song spans at least seven octaves from 80 Hz for the spruce grouse (Dendragapus canadensis) to 11 kHz for the cowbird (Molothrus ater). Noises in display may also be produced by other means. The use of a given sound structure depends on the physical characteristics of the habitat in which it is commonly used. The avian ear is similar in peak sensitivity to that of mammals, with the more sensitive region between 1.5 kHz and 4 kHz. The avian ear, however, falls off more rapidly in sensitivity with increasing and decreasing frequency. Environmental noise, such as wind and falling rain, is predominantly of low frequency, and the avian ear acts as a high-pass filter to filter out incoming sounds at lower frequencies. The relation of song to behavior is briefly discussed.

Knudsen, E.I. 1981. The hearing of the barn owl. Sci. Am. 246(6):113-125.

The barn owl (Tyto alba) is a nocturnal hunter that relies solely on its hearing to locate field mice by the rustling and squeaking sounds they make as they traverse runways in snow or grass. The most striking anatomical feature of the barn owl, which also plays the most important role in its location of prey, is the face. The facial ruff forms a surface that is an efficient reflector of high-frequency sounds. The owl's ears are asymmetrical, which allows the bird to discern elevation. The subtle differences in timing and loudness detected by the owl's unique hearing structure provide enough information for the bird to accurately locate sounds both horizontally and vertically. Although the owl's hearing is sensitive to a broad range of frequencies (from 100 Hz to 12,000 Hz), it can accurately locate only sounds with frequencies between 3,000 and 9,000 Hz.

Knudsen, E.I. 1978. Strategies for sound localization in birds. J. Acoust. Soc. Am. 64(Suppl. 1):S4. [Abstract.]

The ability of an animal to localize sound is correlated with its ethological niche. Birds face a particularly difficult task in sound localization because they must localize well in both azimuth and elevation; the azimuth of a target is of no use to an airborne predator unless it can also determine the target's elevation. Furthermore, birds must perform sound localization with access to only a limited range of low sound frequencies (<12 kHz), with heads that provide little sound shadow and ears that have no pinnae and are close together. Behavioral, physiological, and anatomical data suggest, however, that the auditory systems of birds are capable of extremely fine time resolution. Birds have elaborated a large, patent air canal connecting their two middle ears, which might improve the directional properties of their ears. Some birds have developed asymmetrical ears that cause interaural time and interaural intensity cues to assume different axes of symmetry. These adaptations permit birds to achieve a high level of sound localization ability, the best which rivals and may exceed that of man.

Knudsen, E.I., M. Konishi, and J.D. Pettigrew. 1977. Receptive fields of auditory neurons in the owl. Sci. 198:1278-1280.

The influence of sound location on the responses of auditory neurons in the forebrain of the barn owl (Tyto alba) was studied directly using a remote-controlled, movable sound source under free-field, anechoic conditions. Some auditory neurons demonstrated well-defined receptive fields that were (1) restricted both in elevation and azimuth, and (2) relatively independent of the intensity and the nature of the sound stimulus. The majority of the fields were located frontally and contralateral to the recording site. The owl maintains maximum spatial acuity when a target sound includes frequencies of only 5-9 kHz, and is quite accurate at localizing even a 7-kHz pure tone.

Kohler, D. 1973. A behavioral audiogram of a juvenile carp. Experientia 29:125-127.

Audiograms of two juvenile carp (Cyprinus carpio) were determined in a series of behavioral experiments. Temperature of the water varied from 19 to 22 °C during the tests. The upper threshold was 3,000 Hz (26 dB); lower limit was at least 100 Hz (-14 dB), but could not be measured beyond this. Peak sensitivity was from 400 Hz (-22 dB) to 900 Hz (-25 dB), within the region found in other cyprinids.

Konagaya, T. 1980. Response of fish to low-frequency sound. Bull. Japanese Soc. Sci. Fish. 46(2):125-128. [English summary.]

Fish generate extremely low-frequency sound by the motion of the fin or body in water and use this sound for mutual communication in schooling. Therefore, fish may be able to perceive the low-frequency sound produced by the motion of objects in water. This study examines the response of fish to low-frequency underwater sound produced by the motion of fish and fishing gear in the water. Fish and fishing gear produced short pulses by their motion in water. A rapid pressure change was detected at the mouth of a wingless model dragnet. Fish responded to pulsating sound or the pressure change in water by rapidly swimming or by flipping their tails.

Konagaya, T. 1980. Jumping response of aya to sound. Bull. Japanese Soc. Sci. Fish. 46(1):31-34. [English summary.]

While ascending streams from the sea to the upper river, the fry of aya (Plecoglossus altivelis) have a strong anadromous character and show jumping response not only in waterfalls but also to underwater sound. The jumping response of this fish to underwater sound was studied, and the most sensitive freqency was about 200 Hz; however, the sensitivity of the fish was not determinable above 600 Hz. The lowest threshold level of underwater sound for jumping response was 72 dB (1 uPa) at 200 Hz. The numbers of fish responding to the sound pressure were distributed as described by a normal curve in the range of 70 to 80 dB (1 uPa).

Konagaya, T. 1980. The sound field of Lake Biwa and the effects of the constructing sound on the behavior of the fish. Bull. Japanese Soc. Sci. Fish. 46(2):129-132. [English summary.]

To clarify the effects of construction sounds on fish populations, the change of acoustic environments of Lake Biwa (Japan) by dredging was observed. The response of fish to dredging sound and swimming direction of fish near the worksite were studied by the use of acoustic biotelemetry. The spectrum level of the background noise of Lake Biwa was within the limits of prevailing noise of the sea. Pressure level of the underwater sound of a dredging boat at a distance of 150 m was about 38 dB, and that of a submerged pipe at a distance of 2 m was 75 dB. The fish showed negative responses and avoided the acoustic field of the worksite.

Konishi, M. 1973. Locatable and nonlocatable acoustic signals for barn owls. Am. Nat. 107(958):775-785.

Physical parameters of sound that affect acoustic location in the barn owl (*Tyto alba*) were studied. The frequency of pure tone best suited for location was 7-8 kHz. Above and below this range, error of location increased. Tone bursts did not consistently give better location clues than sustained tones. Neither binaural phase nor time differences seemed to be used for location. The owl located wide-band noises containing frequencies optimal for location more accurately than narrow-band and pure-tone signals.

Konishi, M., and A.S. Kenuk. 1975. Discrimination of noise spectra by memory in the barn owl. J. Comp. Physiol. 97:55-58.

Barn owls (*Tyto alba*) learned and remembered complex noise spectra and distinguished them from slightly different spectral patterns. Threshold of discrimination could not be determined because the minimum reliable spectral difference produced by the spectral equalizer was an amplitude difference of plus or minus 2.5 dB at one of the center frequencies, which the owls could easily detect.

Konstantinov, A.I. 1978. Functional adaptations of the mammalian auditory system. Page 319 *in* R. Obrtel, C. Folk, and J. Pellantova, eds. Abstracts of papers. II. Congressus Theriologicus Internationalis, Brno, Czechoslovakia.

The basic characteristics of hearing, communication, and orientation signals were investigated in 30 species of insectivores, chiropterans, rodents, pinnipeds, and cetaceans. The sensitivity of hearing, range of reception, and time parameters were found to be distinctly dependent on ecological factors and the acoustics of the environments of the animals under study. Animals with exclusively underground life habits [moles (*Spalax* spp., *Mogera* spp.)] showed hearing of the lowest frequency and relatively high thresholds. A considerable extension of the reception range into the ultrasound frequency zone, with a lowering of the thresholds and more rapid response to the subsequent acoustic signals, was ascertained in species of largely nocturnal life habits or those showing polyphasic diel activity patterns. The acoustic system is most refined in animals using ultrasound echolocation for orientation and searching for prey in a tridimensional space, under optically unfavorable conditions (chiropterans, cetaceans). Data are presented on the decisive capabilities of hearing and on the development of acoustic centers in the cerebrum of the various representatives of the groups under study.

Kovalcik, K., and J. Sottnik. 1971. The effect of noise on the milk efficiency of cows. Zivocisna Vyroba 16:795-804.

Noise as high as 80 dB had no effect on dairy cows. Feed intake was increased, milk yield was unchanged, and indices of the rate of milk-releasing were improved. Immediate exposure to a high-intensity noise (105 dB) resulted in decreased feed consumption, milk yield, and intensity of milk release. Gradual increase of noise to 105 dB resulted in a less-negative response.

Kreithen, M.L., and D.B. Quine. 1979. Infrasound detection by the homing pigeon: a behavioral audiogram. J. Comp. Physiol. 129:1-4.

Homing pigeons could detect extremely low-frequency sounds (infrasounds), as low as 0.05 Hz in a sound isolation chamber. Classically conditioned heart rate changes were used as a behavioral measure of sensitivity. An audiogram of thresholds was determined for 13 frequencies between 0.05 Hz and 200 Hz. Below 10 Hz, the pigeons were at least 50 dB more sensitive than humans. Surgical removal of middle ear or inner ear structures reduced or eliminated the infrasound responses. Natural infrasounds come from many sources, including weather patterns, topographic features, and ocean wave activity. Infrasounds propagate long distances and can be detected hundreds or even thousands of kilometers away from their sources. These laboratory experiments are part of a series designed to find out if homing pigeons can use outdoor infrasounds as cues for orientation and navigation.

Kull, R.C., and A.D. Fisher. 1986. Supersonic and subsonic aircraft noise effects on animals: a literature review. Air Force System Command, Noise and Sonic Boom Impact Technology, Wright-Patterson Air Force Base, Ohio. 51 pp.

Literature related to the effects of sonic booms and subsonic noise on birds, mammals, and fish is reviewed and summarized in table form and includes the type of animal (species, group), type of sound, effects, method used to collect the data, and implications. The text also includes sections on general noise effects and methods, impacts on the Air Force (including claims made against the Air Force due to noise), habituation of animals to noise, and areas for further investigation into the effects of noise on animals.

Kushlan, J.A. 1979. Effects of helicopter censuses on wading bird colonies. J. Wildl. Manage. 43:756-760.

Behavioral responses of wading birds to helicopter flyovers at a nesting colony in southern Florida were compared to responses during fixed-wing aircraft flyovers at altitudes of 60 and 120 m. In all tests with aircraft, no bird that left its nest failed to return within 5 minutes. In 90% of the observations, birds either showed no reaction or merely looked up. In tests conducted with great egrets (*Casmerodius albus*), snowy egrets (*Egretta thula*), and Louisiana herons (*Hydranassa tricolor*), the helicopter caused the same or less disturbance with the exception of one test with snowy egrets when the helicopter flew at an altitude of 60 m. The author recommends individual tests at specific sites before use of a helicopter for censusing wading birds at other locations and discusses procedures to help minimize possible effects of aircraft near colonies.

Lagardere, J.P. 1982. Effects of noise on growth and reproduction of Crangon crangon in rearing tanks. Marine Biol. 71:177-185.

Brown shrimp (Crangon crangon) were reared in Angoulins, France, from April to June 1981. Rearing in a soundproof box reproduced acoustical conditions similar to those prevailing in the shrimp's natural environment. Growth and reproduction were compared to those of shrimp from the same source but reared in acoustical conditions prevailing in a thermoregulated aquarium, where noise levels reached 30 dB in the 25- to 400-Hz range. This permanently high sound level resulted in a significant reduction in growth and reproduction rate of the shrimp. To a lesser degree, noise also appeared to increase aggression (cannibalism) and mortality rate and to decrease food uptake. These symptoms are similar to those induced by adaption to stress.

Langley, W.M. 1979. Preference of the striped skunk and opossum for auditory over visual prey stimuli. Carnivore 2(1):31-34.

Predatory mammals can track moving prey at a distance by vision or audition. In tests where various combinations of vision and audition were deprived and latencies of attack measured, striped skunks (Mephitis mephitus) and opossums (Didelphis virginiana) preferred auditory to visual stimuli. Several other predatory mammals that hunt under similar conditions as the skunk and opossum showed the same preference.

Liberman, M.C., and D.G. Beil. 1979. Hair cell condition and auditory nerve response in normal and noise-damaged cochleas. Acta Otolaryngal. 88:161-176.

Histological and physiological data were compared from domestic cats born and raised in a low-noise chamber and cats obtained from a local animal supplier and raised in a noisy laboratory environment (0.75, 1.5, 3, or 6 kHz). Noise-induced threshold shifts were correlated with loss or damage to the hair cells in cochleas of noise-exposed cats. The hair cells were significantly more disorderly in noise-exposed than in nonexposed cats.

Luz, G.A., and J.B. Smith. 1976. Reactions of pronghorn antelope to helicopter overflight. J. Acoust. Soc. Am. 59:1514-1515.

On a mesa in New Mexico, reactions of pronghorns (Antilocarpa americana) to helicopters were assessed by aerial photography. At an altitude of 400 ft and a slant range from the herd of 3,000 ft, no reactions could be observed. Mild reactions (muscle tensing and interruption of grazing) were observed as the craft moved toward the herd at a descent rate of 200 ft/min and a forward air speed of 40-50 knots. Strong reactions (running) began when the craft was at 150-ft altitude and a slant range of 500 ft. Calculated noise levels of no reaction and strong reaction were approximately 60 and 77 dBA, respectively.

Lynch, T.E., and D.W. Speake. 1978. Eastern wild turkey behavioral responses induced by sonic boom. Pages 47-61 *in* J.L. Fletcher and R.G. Busnel, eds. Effects of noise on wildlife. Academic Press, New York.

Twenty wild turkey (*Meleagris gallapavo*) hens near Saco, Alabama, were captured and equipped with 164-MHz transmitters, and their nest sites were located by telemetric triangulation. The behavior of four hens on their nests was observed during real and simulated sonic booms. Flight level above ground and type of aircraft producing the sonic booms was not stated in the paper, but the magnitude of the overpressures recorded from the airplane-produced sonic booms were "typical of those generated directly beneath the flight path by current supersonic transports such as the British-French Concorde and the Russian TU-144." Simulated sonic booms were produced by firing 5-cm mortar shells, 300-500 ft from the nest of each hen. Recordings of pressure for both types of booms measured 0.4-1.0 psi at the observer's location. Hens exhibited only a few seconds of head alert behavior at the sound of the sonic boom. No hens were flushed off the nest, and productivity estimates revealed no effect from the booms. Twenty brood groups were also subjected to simulated sonic booms. In no instance did the hens desert any poults. No poults scattered or became lost from the rest of the brood group. In every observation, the brood group returned to normal activity within 30 seconds after a simulated sonic boom. The authors concluded that sonic booms in this study did not initiate abnormal behavior that would result in decreased productivity in wild turkeys.

Majeau-Chargois, D.A. 1970. The effect of sonic boom exposure to the guinea pig cochlea. Natl. Aeronatics and Space Admin., Rep. No. NASA-CR-1022461. 17 pp.

Thirty guinea pigs with normal hearing were used in simulated sonic boom experiments. Six guinea pigs were used as controls, and eight each were exposed to 1,000 sonic booms at approximately 130 dB of 2, 4.76, and 125 msec N-wave pulse duration. The cochleae were dissected, stained with osmium tetroxide, and the organ of Corti removed for histological examination. Hair cell damage was noted in the apical turn of the cochleae of the exposed guinea pigs.

Marcellini, D.L. 1974. Acoustic behavior of the gekkonid lizard, *Hemidactylus frenatus*. Herpetol. 30:44-52.

Calls of the gekkonid lizard (*Hemidactylus frenatus*) were evaluated in the laboratory and in the field (Ciudad Valles Desert of Mexico). *Hemidactylus* has a vocal repertory of three functionally, physically distinct calls that are important in its social behavior. The multiple chirp call (used by both sexes) was the most common call and was closely associated with agnostic behavior and territorial defense. The dominant frequency of each chirp varied from 1,500 to nearly 2,500 Hz; harmonics reached frequencies of over 14,000 Hz. The churr call was used only in close encounters by males. The single chirp call, frequently heard by both sexes, was closely associated with distress and

may facilitate escape from predators. The acoustic behavior of *H. frenatus* is compared to that of other species of geckos and discussed in relation to environmental and behavioral factors.

Marler, P., M. Knoshi, A.J. Jutjin, and M.S. Waser. 1973. Effects of continuous noise on avian hearing and vocal development. Proc. Natl. Acad. Sci. 70:1393-1396.

Continuous loud noise of 95-100 dB was used to mask auditory feedback from vocal behavior of male canaries (*Serinus canarias*). Longer exposure caused greater deficits with losses of high-frequency sensitivity. After the noise exposure was terminated, there was significant song recovery, presumably as a result of restoration of the birds' ability to hear their own song.

Merzenich, M.M., L. Kitzes, and L. Aitkin. 1973. Anatomical and physiological evidence for auditory specialization in the mountain beaver (*Aplodontia rufa*). Brain Res. 58:331-344.

An examination of brain stem auditory nuclei in a comparative series of 105 mammals revealed that the mountain beaver (*Aplodontia rufa*) had a relatively large and unique cochlear nuclear complex. The dorsal cochlear nucleas in this species were 4-7 times larger than in any of 17 other rodent species examined. Study of single units in the specialized dorsal cochlear nucleas revealed that many neurons responded to exceptionally low-frequency stimuli (below 10 Hz). Thresholds of neurons were relatively high and response areas relatively flat in comparison with responses of neurons in the ventral nucleus. Neurons isolated within the large granule cell field could not be excited by tonal or other simple acoustic stimuli. These data suggested that part of the unique auditory system in the mountain beaver is specialized for the detection of slow changes in air pressure.

Miller, E.H. 1985. Airborne acoustic communication in the walrus (*Odobenus rosmarus*). Natl. Geogr. Res. 1(1):124-145.

The structure and behavioral use of common classes of airborne sounds in walruses (*Odobenus rosmarus*) were studied in the Bering and Chukchi seas. Acoustic communication was an integral component of nearly all social interactions on land or ice, and contained at least seven structurally defined classes. Calls ranged from rapidly repeated, wide-band pulse, guttural sounds, which occurred at rates as low as 13 Hz, to the loud bark or bellow where energy was concentrated between 300-500 Hz. Spectrograms of various calls of walruses are included in the paper.

Milligan, J.E., B.W. Martin, and C.E. Thalken. 1983. Handbook of veterinary claims. Natl. Tech. Inf. Serv., Springfield, VA. 75 pp.

This handbook serves as a guide for claims officers and appointed investigating veterinarians or other experts to process claims against the U.S. Air Force for damage to domestic animals, fowl, fish, and wildlife. Eight case studies are discussed in the appendices. Seven of the cases involved claims concerning domestic animals and aircraft noise. Opinion summaries of an additional 12 claims are also included. The role of the U.S. Air Force Occupational and Environmental Health Laboratory, Brooks Air Force Base, Texas, is also explained with regard to claims.

Moller, A. 1978. Review of animal experiments. J. Sound and Vibration 59:73-77.

The results of short-term animal experiments show that noise can evoke several acute changes in a number of bodily functions. The best known of these reactions are those that influence circulation and release of pituitary gland hormones. It is not known if the different acute reactions to noise can result in disease or shortening of the life span. The effect of long-term exposure to noise is not yet known, primarily because so few studies have been done. It appears that noise alone does not give rise to abnormal hypertension.

Moseley, L.J. 1979. Individual auditory recognition in the least tern (Sterna albifrons). Auk 96:31-39.

Playback experiments performed in a colony of least terns (Sterna albifrons) near Fort Macon, North Carolina, demonstrated that adults can distinguish the call of their mate from that of a stranger. Sonagram analysis of the "purrit-tit-tit" call, the most common vocalization used when an adult approaches its mate, revealed that both temporal and spectral characteristics of the first note of the call varied significantly among individuals, whereas all measured features of the second note were not significantly different for different birds. Presumably, the first note is used to convey an individual's identity, while the second note indicates a tendency to approach the mate and perform certain courtship behaviors.

Myrberg, A.A., Jr. 1978. Ocean noise and the behavior of marine animals: relationships and implications. Pages 169-208 in J.L. Fletcher and R.G. Busnel, eds. Effects of noise on wildlife. Academic Press, New York, NY.

Acoustical noise and its effects on selected marine biological systems are reviewed. The scope of the review was limited to relevant findings concerning marine fishes and selected marine mammals, primarily the olontocete cetaceans and pinnipeds, because little or nothing is presently known about the subject in other groups. Only the shallow coastal regions of the Continental Shelf are discussed because they represent the major habitats of these animals. Topics include: shallow water ambient noise levels, sound detection and localization by fishes and marine mammals, the relationship between audibility and environment noise, and the effects of environmental noise on the hearing ability of marine fish and mammals. The paper is a thorough review of the available literature on ocean noise and the hearing ability of marine fish and mammals.

Myrberg, A.A., Jr., and J.Y. Spires. 1980. Hearing in damselfishes: an analysis of signal detection among closely related species. J. Comp. Physiol. 140:135-144.

Audiograms were established for six closely related damselfishes (Eupomacentrus spp.) from the coastal waters of southern Florida and compared to a previously established audiogram of a cogeneric. Although variation existed, mean threshold values for all species clustered within 10 dB at any frequency. Ascending slopes of threshold sensitivity on either side of their common, most sensitive frequency--500 Hz (-16 dB/1 μbar), approximated 15 dB/ octave at lower frequencies and 40 dB/octave between 500-1,200 Hz.

Nakamura, A., and T. Ishida. 1983. Measurement of yellowtail (Seriola quinqueradiata) response to light and sound stimuli, using ultrasonic high sensitivity transmitter with depth factor. J. Fac. Mar. Sci. Tech., Tokai Univ. No. 17:85-95. [English abstract.]

An ultrasonic high sensitivity transmitter was used to estimate the vertical motion of yellowtails (Seriola quinqueradiata) given a sudden stimulus by light or sound; precision of the transmitter of depth information was plus or minus 10 cm. The average interval of telemetering information from the swimming fish was about 0.4 second. When the stimulus was given to the yellowtail, the fish went down at once. The "escape time" was defined as the time from the escape to the return to the initial swimming layer.

Nawrot, P.S., R.O. Cook, and R.E. Staples. 1980. Embryotoxicity of various noise stimuli in the mouse. Teratology 22:279-289.

Female mice were exposed from days 1-6 or days 6-15 of gestation to one of three noise paradigms: semicontinuous, extremely high-intensity jet engine noise at 126 dBA; startling type noise of alarm bells, jet noise, or warning devices at 110 dBA; and high-frequency noise (18-20 kHz). Significantly decreased pregnancy rate was noted in all groups except the one exposed to high-frequency noise on days 6-15 of gestation. Significant embryolethal effects occurred in the mice exposed to extremely high-intensity jet noise from days 1-6 of gestation, and significant fetolethal effects occurred in mice exposed to the high-frequency noise on days 6-15 of gestation.

Nayfield, K.C. and E.L. Besch. 1981. Comparative response of rabbits and rats to elevated noise. Lab. Anim. Sci. 31(4):386-390.

Laboratory rabbits and rats were exposed to 15 hours of white noise per day at intensities of 107-112 dB. Compared to the control condition of 60 dB, both rabbits and rats displayed increased adrenal weights. Rabbits also had decreased spleen and thymus weights. Rats had increased total leukocyte counts and a relative eosinopenia. Noise-exposed rats also showed decreased food intake by the third day. No changes in plasma protein concentrations were observed.

Nieboaer, E., and M. van der Paardt. 1977. Hearing of the African woodowl, Strix woodfordii. Netherlands J. Zool. 27:227-229.

Hearing threshold values were determined for the African woodowl (Strix woodfordii). At frequencies from 0.5-6 kHz, threshold values were between -4.5 and -15 dB, and at 8 kHz, this value was +27.5 dB. The hearing thresholds of the African woodowl and two other tropical woodowl species are lower than those measured in temperate woodowls, thus supporting a previously stated hypothesis that directional hearing in species from tropical forests is poorer than in temperate woodland species. Asymmetry and complexity of external ear structures in woodowls also increases from the tropics to temperate and boreal woods. The silent winter nights of northern regions might have favored specialization for prey location by directional hearing. The omnipresence of noise in the tropical forest hampers location of one single prey by hearing.

Nikol'skii, I.D. 1975. Bioacoustic signal field as a factor in adaptive behavior of animals. Ekologiya 7(2):13-18.

Specific characteristics and criteria of the biological signal field are discussed. Certain functional aspects of the bioacoustic component of the signal field are examined, in particular the defensive aspect. The bioacoustic component of the field is actualized both by summation of sounds in an animal group and by ritualized signals eliciting group adaptive responses. The latter play an important mediatory role in the transfer of information in bird groups.

Nixon, C.W., H.K. Hille, H.C. Sommer, and E. Guild. 1968. Sonic booms resulting from extremely low-altitude supersonic flight: measurements and observations on houses, livestock, and people. Defense Documentation Center, Alexandria, VA. Aerospace Med. Res. Lab. Rep. No. TR-68-S2. 22 pp.

Sonic booms generated by F-4C aircraft flying low-level (85-125 ft AGL) profiles during Joint Task II operations near Tonapah, Nevada, were recorded under and near the flight tracks, and responses of structures, livestock, and people were observed. Recorded overpressures up to 144 psf were analyzed, correlated with available aircraft operations data, and compared with data from different aircraft flying similar profiles. Observations of structures, livestock, and people were correlated with the measured overpressures. Results include (1) acquisition of near-field recordings of overpressures generated by the F-4C, (2) the finding that some window glass fragments were propelled a short distance rather than falling directly below the window, (3) an instance in which the measured overpressure of a sonic boom 1 mi to the side of the track far exceeded the predicted value, (4) the finding that livestock (undetermined prior exposure to acoustic stimuli in this situation) did not apparently respond adversely to the sonic booms, (5) confirmation that intense sonic booms do not harm people directly, and (6) the reaffirmation that the selection of site locations for low-level supersonic training missions will continue to pose a problem.

Ogle, C.W., and M.F. Lockett. 1966. The release of neurohypophyseal hormone by sound. J. Endocrin. 36:281-290.

Recorded thunderclaps at 98-100 dB increased the urinary excretion of sodium and potassium of normal rats but not neurohypophysectomized rats. The urinary changes induced by replayed thunder were attributable to release of oxytocin together with a lesser amount of vasopressin. By contrast, a sound frequency of 150 Hz probably released oxytocin alone.

Peterson, E.A., J.S. Augenstein, D.C. Tanis, and D.G. Augenstein. 1981. Noise raises blood pressure without impairing auditory sensitivity. Sci. 211:1450-1452.

Two rhesus monkeys exposed continuously for 9 months to realistic patterns and levels of noise (85 dB-flat, 97 dB-peak; 200 Hz) showed sustained elevations in blood pressure, which did not return to baseline after noise exposure had ended. Auditory brainstem responses measured before and after exposure, indicated no change in auditory sensitivity.

Popper, A.N., and N.L. Clarke. 1976. The auditory system of the goldfish (Carassius auratus): effects of intense acoustic stimulation. Comp. Biochem. Physiol. 53A:11-18.

Effects of intense pure tone stimulation (300, 500, 800, and 1,000 Hz) on auditory thresholds of the goldfish (Carassius auratus) were measured in behavioral experiments. Stimulation at 300 and 500 Hz produced lower threshold shifts than at 800-1,000 Hz. Results indicated that the teleost inner ear responds in relatively complex fashion to different stimulating frequencies, possibly indicating some degree of spatial signal analysis in the inner ear.

Popper, A.N., and W.N. Tavolga. 1981. Structure and function of the ear in the marine catfish, Arius felis. J. Comp. Physiol. 144:27-34.

Investigations were conducted on hearing capabilities and the structure of the inner ear in the marine catfish (Arius felis). Behavioral audiograms, determined using avoidance conditioning techniques, showed that the catfish was able to detect sounds from 50-1,000 Hz, with best hearing sensitivity from 100-200 Hz. This was in contrast to the hearing abilities of other Ostariophysi, which can detect sounds to over 3,000 Hz and have best hearing sensitivity at about 500-1,000 Hz. The utricle of Arius is larger and has a different pattern of sensory epithelium than that of other Ostariophysi. The authors conclude that the auditory system in *Arius* is adapted for hearing low-frequency sounds used in the detection of objects through echolocation.

Poussin, C. 1982. Low-frequency hearing sensitivity in the echolocating bat (*Eptesicus fuscus*). M.S. Thesis. University of Oregon, Eugene. 50 pp.

Big brown bats (*Eptesicus fuscus*) use sound at frequencies from 10 to 100 kHz for sonar or for acoustic social communication, and they also hear these ultrasonic frequencies. The bats also have a lower-frequency region of auditory sensitivity from 200 Hz to 5 kHz. They may use these lower frequencies to detect insect prey by passive hearing of the insect's own sounds. The hearing is tuned to 0.7 to 1.3 kHz, indicating that some specialization of the auditory system, perhaps in the external or middle ear, may underlie the capacity to hear these lower frequencies. The results also suggest some specific role for low-frequency hearing in the bat's life; the brown bat orients toward the sound produced by insects under natural conditions.

Pritchett, J.F., M.L. Browder, R.S. Caldwell, and J.L. Sartin. 1978. Noise stress and in vitro adreno-cortical responsiveness in ACTH in wild cotton rats, *Sigmodon hispidus*. Environ. Res. 16:29-37.

Wild cotton rats (*Sigmodon hispidus*) collected in the spring and autumn were exposed to high-intensity intermittent noise (110 dB SPL). The animals' adrenal glands were weighed and incubated in either the absence or presence of adrenocorticotrophic hormone (ACTH). ACTH elicited a significantly smaller response (in terms of corticosterone secreted) in the noise-exposed groups within either season, compared to the controls, and in the autumn control group compared to the spring control group. ACTH also induced significantly smaller cyclic adenosine monophosphate (cAMP) accumulations in noise-exposed rats compared to control animals. The data suggested that noise stress plus seasonal factors may restrict the animal's ability to respond to physiological stressful stimuli.

Quine, D.B. 1979. Ultralow frequency discrimination: can homing pigeons localize infrasounds by Doppler shifts? J. Acoust. Soc. Am. 65(Suppl. 1):S39. [Abstract.]

Homing pigeons detect infrasounds at frequencies as low as 0.05 Hz. Frequency discrimination at infrasonic frequencies (1, 2, 5, and 10 Hz) is essentially as good as that at "audible" frequencies. Experiments indicated that true frequency discrimination, rather than amplitude discrimination, is being used. Because homing pigeons fly at about 6% the speed of sound, they can produce Doppler shifts in flight of plus or minus 6%. Pigeons in the laboratory can detect such frequency shifts. A Doppler shift mechanism may provide cues for localization of outdoor infrasonic sources. The interaural differences of intensity and phase probably are too small to use at infrasonic frequencies (wavelengths are tens or thousands of meters).

Rajender Kumar, P.V., S. Kameswar, M.V. Rajendran, and M.N. Kutty. 1976. Responses of certain fishes and snakes to sound. J. Bombay Natl. Hist. Soc. 73:88-93.

Responses of four species of fishes and three species of snakes to sound (10 dB to +50 dB) were determined in behavioral experiments. Ostariophysid fishes had a better hearing range (up to 4,000 Hz) than non-ostariophysids (up to 1,500 Hz). Hearing thresholds between ostariophysids and non-ostariophysids was similar (20-30 dB). Snakes did not respond to pure tone irrespective of the frequency or intensity, whereas they responded to music (mixed tones) that was of predominantly low frequency, and the response was chiefly one of fright.

Reinis, S. 1976. Acute changes in animal inner ears due to simulated sonic booms. J. Acoust. Soc. Am. 60:133-138.

Mice were subjected to simulated sonic booms of different rise time, intensity, and number of sonic booms. Exposure resulted in bleeding in the basal turn of the scala typani of the inner ear. The frequency of blood clots in the scala typani was found to increase with the number of booms administered. The traces of bleeding usually disappeared within 8 weeks after exposure.

Rennison, D.C., and A.K. Wallace. 1976. The extent of acoustic influence of off-road vehicles in wilderness areas. Pages 169-183 in J.P. Wood and R.W. Robertson, eds. Off-road vehicles: some policy, planning, and management considerations. Proc. Natl. Symposium on Off-road Vehicles in Australia, Australian Inst. of Parks and Recreation, Northcote, Victory, Australia.

Substantial evidence exists in the literature that off-road vehicle (ORV) noise constitutes a strong disturbance to the habits of native fauna and consequently interferes with the recreation of those observing fauna. The authors present a theoretical model that describes the variation of noise level with distance from the noise source. Criteria were established that defined the distance of acoustic influence as the distance at which the noise level was raised 3 dB above the ambient background noise. Field tests confirmed that the theoretical model adequately describes the propagation. Using a background sound pressure level of 30 dB (supported by the literature and field measurements), the model predicted that one production trail bike could be audible for a distance of 3 km in open country (no hills or structures); 10 trail bikes could be audible for 4 km. A possible planning procedure and a case study that dealt with the acoustic field of influence of ORV's was presented. The authors recommended (1) using areas for ORV recreation that have higher background noises, such as areas adjacent to freeways, quarries, and industrial complexes, thus not significantly altering the background level; and (2) legislative action to lower ORV noise levels, including control over the modification of exhaust systems on production ORV's.

Renouf, D. 1985. A demonstration of the ability of the harbor seal, *Phoca vitulina* (L.), to discriminate among pup vocalizations. J. Exp. Marine Biol. and Ecol. 87:41-46.

A captive adult female harbor seal (*Phoca vitulina*) distinguished between vocalizations recorded from different pups, supporting the implication of an earlier study that a pup's call is an individual characteristic and might, therefore, provide one means by which the mother could recognize her offspring and monitor its location. Calculations using the 25-dB critical ratio of harbor seals, a 70-dB pup call, and noise levels of 25 dB (spectrum) indicated that the mother should not be able to hear her pup's cry once the pair are separated by more than 8 m.

Rice, W.R. 1982. Acoustical localization of prey by the marsh hawk: adaption to concealed prey. Auk 99:403-413.

The acoustic location capacity of the northern harrier (*Circus cyaneus*) was measured in both the laboratory and the field. Laboratory experiments indicated that the directional hearing of the harrier was substantially better than that of a sample of typical diurnal raptors and similar to that of owls capable of capturing prey in total darkness. Angular resolution along the horizontal axis was 2 degrees for the harriers, 1-2 degrees for the owls, and 8-12 degrees for the sample of typical diurnal raptors. For the harriers, angular resolution along the vertical axis was at least 2 degrees. The maximum range on sonic prey detection was estimated at 3-4 m for the harrier and 7 m for the barn owl (*Tyto alba*). Field experiments indicated that free-ranging harriers could locate vole vocalizations (squeaks) accurately and attack prey successfully without the aid of visual or olfactory cues. Additional field experiments were conducted to determine how the harrier integrates auditory and visual cues while capturing concealed prey. These experiments show that the harrier does not require motion cues or auditory depth perception to determine the elevation of a sound source.

Rucker, R.R. 1973. Effect of sonic boom on fish. Dep. Transportation, Fed. Aviation Admin., Washington, DC. Rep. No. FAA-RD-73-29. 67 pp.

The effect of sonic booms on fish and fish eggs during critical stages of development was studied at several National Fish Hatcheries in Nevada, Oregon, and Washington. During development, fish eggs reach a critical period when they become sensitive to vibration or disturbance (usually from after the first 24 hours until the "eyed stage" of development). Fish eggs from cutthroat trout (*Salmo clarki*), steelhead and rainbow trout (*Salmo gairdneri*), and chinook salmon (*Oncorhynchus tshawytscha*) were exposed to sonic booms produced by military jets (F-111 or F-101) or simulated sonic booms of varying pressure (maximum of 4.16 psf). Exposure varied from a single sonic boom to repeated exposures over several days. Comparisons with control groups of eggs spawned at the same time indicated that sonic boom exposure caused no increase in egg mortality. Blood glucose levels, blood cortisol levels, and plasma osmolality levels of yearling rainbow trout exposed to sonic booms were similar to those of controls. Behavior observations of yearling rainbow trout exposed to sonic booms indicated "no" to "very slight" reactions to the disturbance.

Ruddlesden, F. 1971. Some observations on the effect of bang type noises on laying birds. Royal Aircraft Establishment, London, UK, Tech. Rep. No. 71084. 24 pp.

The effects of simulated sonic bangs (booms) (50 N/m^2-860 N/m^2) on pheasants (Phasianus colchicus) and lapwings (Vanellus vanellus) were studied during 3 April to 13 June 1968. Two lapwings nested 95-220 m from the boom source and the birds appeared unperturbed by the booms during the study. The process of laying, incubation, hatching, and chick rearing was accomplished in a "natural manner." The daily egg production of a pheasantry located within 0.75 km of the boom source appeared to fall on days subsequent to boom activity; however, when compared with production trends over two other seasons during which no boom activity occurred, the similarities implied that the day-to-day variations were due to some other, unknown influence. The rate of fertility in the pheasantry was highest for the season when sonic booms occurred. The author concluded that the laying habits of pheasants and lapwings will not be adversely affected by the anticipated supersonic flights of transport aircraft; however, observations of lapwings were limited to only two birds.

Ruth, J.S. 1976. Reaction of Arctic wildlife to gas pipeline related noise. J. Acoust. Soc. Am. 60(Suppl. 1):S67. [Abstract.]

Several studies on the reaction of Arctic animals to noise emissions from gas compressors and aircraft are reviewed. Wildlife species examined include caribou (Rangifer tarandus), Dall's sheep (Ovis dalli), moose (Alces alces), grizzly bears (Ursus arctos), wolves (Canis lupus), snow geese (Chen caerulescens), Lapland longspurs (Calcarius lapponicus), and bald eagles (Haliaeetus leucocephalus). Degree of reaction to noise disturbance varied with group size, sex, season, activity engaged in prior to disturbance, previous exposure to noise source, and distance from noise source.

Rylander, R., ed. 1972. Sonic boom exposure effects: report from a workshop on methods and criteria, Stockholm 1971. J. Sound and Vibration 20:477-544.

This report contains (1) an introduction to sonic boom exposure effects, (2) a discussion of the sonic boom--generation and propagation, (3) general considerations on sonic boom research, and (4) six reports from the workshop on structures and terrain, sleep effects, startle responses, annoyance reactions, effects on animals, and sonic boom generators. The report provides a synthesis of pertinent aspects of sonic booms and summaries of available literature on effects of sonic booms on humans and animals. Effects on animals include summaries of research involving field studies based on real and simulated sonic booms, and laboratory studies based on simulated sonic booms. Available data on effects of sonic booms on wildlife and domestic animals are limited. The greatest research need in this area is for critical observation of the response of aggregations of various social mammals and birds to sonic booms of measured overpressure and duration.

Rylander, R., S. Sorensen, B.O. Andrae, G. Chatelier, Y. Espmark, T. Larsson, and R.I. Thackray. 1974. Sonic boom exposure effects--a field study on humans and animals. J. Sound and Vibration 33:471-486.

The presence of startle reaction in humans was assessed by using a hand-steadiness, heartbeat, and tracking test. Reactions of livestock and birds were studied by filming, and observations were recorded on tape. The reactions among animals were small, with slight startle responses among all species studied. A strong habituation effect was observed.

Sackler, A.M., A.S. Weltman, M. Bradshaw, and P. Jurtshuk, Jr. 1959. Endocrine changes due to auditory stress. Acta Endocrin. 31:405-418.

Female rats were subjected to 1-min or 5-min auditory stimulation with a mean intensity of 110 dB. Intense sound stimulation resulted in weight gain reduction and serious changes in both endocrine weight and histology. Adrenal hyperplasia, partial inhibition of ovarian activity, reduction in weight and vascularity of the uterus, and a loss in liver weight were noted. Significant changes in pituitary cell type occurred. Appetite was affected in sound-stressed animals and food consumption was significantly reduced.

Sasvari, L. 1973. Responsiveness of the great tit to different vocal stimuli. Acta Zool. Acad. Scientarium Hungaricae 19:155-166.

In a series of winter experiments, the locomotory responses of the great tit (*Parus major*) to alarm, anxiety, attracting, and territorial vocalization forms, reproduced through a loudspeaker at time intervals of 1, 3, 5, and 7 seconds, respectively, were appraised. The anxiety churring and the attracting call were most effective in evoking a response from the tits. Reactions were moderate to the territorial song and extremely slight to the alarm call. The perceived acoustic signal influence on the locomotory activity of great tits depended on two fundamental factors: (1) the features of the acoustic signal (including the form of signaling as a process, pitch) and (2) the instantaneous physio-psycho state (mood) of individuals (on the basis of inborn and learned experience of the birds connected with the environmental factors). Percent response to alarm and churring calls was greater during cloudy, precipitous weather versus sunny weather. Percent response to the attracting and territorial calls was greater when the tits were "exploring" versus when they were feeding.

Sawa, M. 1976. The audiogram of the goldfish determined by a heart rate conditioned method. Bull. Fac. Fish. Hokkaido Univ. 27(3.4):129-136.

The audiogram of the goldfish (Carassius auratus) was determined by using a change of the conditioned heart rate in a special test tank designed to minimize the near-field effect. A stable acoustic condition was obtained by suspending the fish in a small cage at a fixed position in the test tank. The sensitive frequencies ranged from 70 Hz to about 4,600 Hz, showing the best frequency around 600 Hz where the mean threshold value was -45.6 dB. A gradual rise below 600 Hz and a relatively sharp turn above 800 Hz were indicated in the audiogram. The method seemed to be useful for a rapid determination of the audiogram of fishes.

Schmidt, R.S. 1971. A model of the central mechanisms of male anuran acoustic behavior. Behav. 39:288-317.

Experiments on anuran acoustic mechanisms are described for the bullfrog (Rana catesbieana) and two species of treefrogs (Hyla spp.). These involve brain lesions, brain stimulations, and the recording of auditory responses from the medulla. These data, as well as data from the literature, are summarized and correlated in the form of a preliminary model of male anuran acoustic mechanisms.

Schusterman, R.J. 1980. Auditory sensitivity of northern fur seals (Callorhinus ursinus) and a California sea lion (Zalophus californianus) to airborne sound. J. Acoust. Soc. Am. 68(Suppl. 1):S6. [Abstract.]

Aerial audiograms were obtained in a specially constructed acoustic chamber from three otariid pinnipeds--two yearling female northern fur seals (Callorhinus ursinus) and a 2-year-old female California sea lion (Zalophus californianus). Behavioral response measurements at 1, 2, 4, 8, 16, 24, and 32 kHz resulted in average thresholds for fur seals at 29, 9, 22, 13, 7, 22, and 34 dB, 0.0002 dyn/cm^2, and at 41, 19, 26, 16, 28, 37, and 61 dB for the sea lion. The thresholds for the fur seals, although inferior in air compared to in water, showed better accommodation for hearing airborne sounds than the phocid pinnepeds (such as the harbor seal).

Schusterman, R.J., and P.W. Moore. 1978. The upper limit of underwater auditory frequency discrimination in the California sea lion. J. Acoust. Soc. 63:1591-1595.

The authors hypothesized that at similar or even greater sensation levels (SL's) the frequency discrimination of the sea lion (Zalophus californianus) in water would be poorer in the range of frequencies between 32 and 48 kHz than it would be between 16 and 28 kHz. Different limens were estimated for frequencies of 16, 24, 28, 34, and 38 kHz. Results clearly supported the hypothesis. Between 16 and 28 kHz, the sea lion could discriminate frequencies 2.0% apart. At 34 kHz, frequency resolution became twice as coarse as it was at 28 kHz. Performance at 38 kHz deteriorated to such an extent that the sea lion was capable only of discriminating frequencies that were 11.2% apart. The present results, showing a loss of good frequency resolution much above 32 kHz in the sea lion despite increased SL as compared to the loss of frequency resolution in phocids (such as the harbor seal) above 60 kHz, are consistent with the notion that one of the major differences between the underwater hearing of otariids and (e.g., the sea lion) and phocids is the high-frequency cutoff. Although the sample of species and individuals involved in behavioral comparisons is small, comparative anatomical evidence supports the idea that in water phocids obtain more spectral information from high frequencies than do otariids.

Schusterman, R.J., and P.W. Moore. 1981. Noise disturbance and audibility in pinnipeds. J. Acoust. Soc. Am. 70 (Suppl. 1):S83. [Abstract.]

Individual fitness in all species of pinnipeds depends to a great extent on the transmission and reception of acoustical information transmitted in the hydrosphere as well as in the atomosphere. Major features of sound detection, pitch perception, and sound localization are available for one, or at the most, two individuals belonging to otariid species, and to four phocids. The latter hear higher frequencies under water than do otariids, and the opposite is true for airborne sounds. Masking hearing threshold experiments using center frequencies of 4, 8, 16, and 32 kHz resulted in critical ratios of 20, 20, 25, and 27 dB for two northern fur seals (*Callorhinus ursinus*) and 30, 32, 34, and 35 db for two ringed seals (*Phoca hispida*). Field observations suggested that startle or flight reactions to airborne noise habituate at different rates for different species, different populations, and different groups within a population as a function of age, sex, and time of day. Observations of captive northern fur seals suggested that orientation toward airborne sounds may be partly a function of their hearing sensitivity.

Schwarz, A.L. 1985. The behavior of fishes in their acoustic environment. Environ. Biol. Fishes 13:3-15.

In recent years, more attention has been paid to fish audition than to sound production. The importance of acoustic signals in the social behavior of most fishes has not been studied. However, available data indicate that more fishes can hear well than can (or do) deliberately produce sounds. This, and the complexity of the teleost auditory system, suggests that a fish's surroundings contain acoustic stimuli that may affect the animal's survival. Fishes show great variation in the frequency range they can hear and in their sensitivity over these frequencies, although related species may exhibit similar auditory capabilities if they inhabit similar acoustic environments. Topics discussed in this paper include sound in water, fish hearing, environmental sounds (natural and artificial), fish responses to the components of the acoustic environment, and directions for future research in the behavior of fishes in their acoustic environment.

Schwarz, A.L., and G.L. Greer. 1984. Responses of Pacific herring, Clupea harengus pallasi, to some underwater sounds. Can. J. Fish. Aquat. Sci. 41:1183-1192.

The behavioral responses of net-penned Pacific herring (Clupea harengus pallasi) to a variety of tape-recorded sounds are described. Sounds recorded in the field from a herring fishing fleet included moving and stationary (idling) vessels, sonar, echo sounder, and deck gear. Natural sounds included rain on the water surface, gull (Larus spp.) cries, killer whale (Orcinus orca) vocalizations, barks of Steller's sea lions (Eumetopia jubatus), and sounds made by herring themselves. Sounds of more uniform structure were created with an electronic synthesizer and played back to herring to determine the relative effectiveness of various combinations (triads) of amplitude and frequency (increasing, decreasing, constant) and temporal pattern (continuous, regularly, or irregularly pulsed tones). Herring did not respond visibly to any of the taped sounds of natural origin or to sonar or echo sounders. Responses were elicited by sounds of large vessels approaching at constant speed, by smaller vessels (but only when on accelerated approach), and by 11 different triads of the electronically synthesized sounds. Alarm and, less frequently, startle were both elicited by those electronic sounds with an essentially instantaneous rise time in amplitude. Herring produced chirps and whistles in addition to feeding and hydrodynamic noises. Chirps consisted of one or several bursts of pulses in the range 1800-3,200 Hz and occurred in bouts. Whistles were narrow-band continuous (unpulsed) sounds of 1,600-2,000 Hz. Captive herring showed no response to playbacks of these sounds.

Shalter, M.D., J.C. Fentress, and G.W. Young. 1977. Determinants of response of wolf pups to auditory signals. Behav. 60:98-114.

Two naive wolf (Canis lupus) pups, unexposed to previous wolf calls, were presented a variety of sound stimuli, including standardized recordings of natural and synthetic adult howls (approximately 200-500 Hz). The greatest and most consistent vocal response was elicited by the "real" howls. The nature of the response depended in part on (1) type of stimulus, (2) number of stimulus presentations, (3) associated manipulations of context, and (4) individual differences in vocal responsiveness. Frequency of pup vocal response varied from approximately 400 to 2,000 Hz. Results are discussed in terms of both extrinsic and intrinsic determinants of an animal's response to communication signals.

Shaw, E.W. 1970. California condor. Libr. Congr., Washington, DC, No. SK351. 10 pp.

The general characteristics, distribution, and population status of the California condor (Gymnogyps californicus) are discussed in this report. Noise from blasting, drilling, and construction are included among the several factors contributing to the declining condor population. When disturbed by noise from blasting, drilling, traffic, or sonic booms, the adults frequently abandon their nests. They seem to be particularly sensitive to noise disturbance. In an effort to protect the condor, the U.S. Department of the Interior ordered a halt to all further oil and gas leasing in the Sespe Condor Sanctuary in 1970; 75% of the condor nesting sites were within or adjacent to the sanctuary.

Shen, J.X. 1983. A behavioral study of vibrational sensitivity in the pigeon (Columba livia). J. Comp. Physiol. 152:251-255.

The pigeon (Columba livia) has a well-developed ability to detect weak vibrations. Using the method of heart-rate conditioning, the vibrational sensitivity was determined for four pigeons at an error probability of $P<0.025$. The threshold-frequency relationships indicated that the greatest sensitivity to vibrational stimuli was in the frequency range from 300-1,000 Hz, with thresholds of about 0.1 μm at 500 Hz. Pigeons can respond not only to the frequency of a stimulus, but also to its intensity. Vibration detection may be crucial for sensing approaching predators, for instance, when birds are sleeping perched on a branch.

Shepherd, J.G., and J.W. Horwood. 1979. The sensitivity of exploited populations to environmental "noise", and the implications for management. J. Cons. Int. Explor. Mer. 38:318-323.

The sensitivity of natural populations to environmental noise is largely determined by their response to transient perturbations. The most important features of the transient response are described by the return time, which is the characteristic time taken for the population to return to equilibrium after perturbation. The return time may either increase or decrease when a population is exploited, depending on the nature of the mechanisms that regulate population size. The sensitivity of population size to noise may either increase or decrease as return time increases, depending on the way in which the "noise" acts to perturb the population. It is thus not possible to make any firm statement about the effect of exploitation on sensitivity to noise without understanding in some detail the regulatory mechanisms and sources of fluctuations for the population in question. Nevertheless, the possibility that sensitivity to noise may be increased by exploitation exists, and should be borne in mind when formulating management strategies.

Shotton, L.R. 1982. Response of wildlife and farm animals to low-level military jet overflight. Rep. II(6):161-164.

Reviewers of Air Force proposals for new low-altitude training routes and military operating areas frequently express concern regarding the effect of jet noise on wildife and farm animals. Differences in noise from low-altitude subsonic overflight and higher altitude supersonic overflight include the increased duration of noise from a low-altitude overflight, the greater probability that noise from low-altitude overflights will be accompanied by visual perception of the aircraft, and the broad-band frequency distribution for jet engine noise (about 200-20,000 Hz) versus the low-frequency noise of sonic booms (with most of the sound energy between 15-50 Hz). Studies on the effects of sonic booms and low-altitude overflights of jets on wildlife and domestic animals are briefly summarized in this article. The author concludes that reported scientific observations and studies regarding the effects of low-altitude jet overflight on animals are not conclusive, and states that "there may be circumstances where it is prudent to avoid low-altitude overflights of wildlife or other animals"; however, most information on this subject indicates that wildlife and farm animals "do not suffer major or long-term adverse effects from low-altitude military jet overflights."

Simmons, J.A. 1983. Localization of sounds and targets in air and water by echolocating animals. J. Acoust. Soc. Am. 73(Suppl. 1):S18. [Abstract.]

Mammals that use echolocation or biological sonar to perceive the locations of objects in their environments have unusual acute capacities for localizing sound (echo) sources and for perceiving reverberation because they rely upon echolocation for spatial perception. Both bats in air and porpoises in water determine the distance to targets from the arrival time of echoes. The sonar signals that they emit are directional, with the possibility that porpoises may transmit different waveforms as well as different signal amplitudes in different directions. The hearing of echolocating animals is also directional, with reception through the external-ear system in bats and through the lower jawbone in porpoises. Directional hearing provides binaural cues for horizontal localization of targets. In bats, the external ear has directional amplitude and phase responses, which the bat uses for vertical localization of targets. In porpoises, it is possible that the transmitted waveform contributes to vertical localization by analogous means. The acuity of localization in echolocating animals is adequate to provide acoustic images of orientation in three dimensions.

Snyder, N.F.R., H.W. Kale, and P.W. Sykes, Jr. 1978. An evaluation of some potential impacts of the proposed Dade County Training Jetport on the endangered Everglades kite. Florida Audubon Soc., Maitland, Florida. 37 pp. [Unpubl. ms.]

This report summarizes two studies on the potential impact of the proposed Dade County Training Jetport near Miami, Florida, on the endangered Florida Everglades kite (Rostrhamus sociabilis plumbeus). An experiment concerning the effects of low overflights of jet aircraft was conducted on a large island colony of kites (15-20 pairs) approximately 2.6 mi west of the proposed jetport runway, during 5 days in early April 1978. Noise levels during overflight varied from 78-89 dBA at the colony. Behavioral response of the kites was limited to "watching the aircraft fly by" (28% of the cases observed). From late April to early May 1978, an assessment was made of the apparent impact of the Barranquilla Airport in Colombia, South America, on Everglades kite populations in the vicinity. The distribution, breeding success, and behavior of the kites provided no clear evidence that the species was being adversely affected by the Barranquilla Airport. The authors suggested that impacts to the habitat by land development associated with the Dade County Jetport could be more detrimental to the kites than the impact of jet noise.

Solntseva, G.N. 1975. Morpho-functional peculiarities of the hearing organ in terrestrial, semiaquatic, and aquatic mammals. *Zool. Zh.* 54(10):8. [English summary.]

Auricle and middle ear have undergone significant changes as mammals have adapted to the aquatic mode of life. Conduction of sound signals in water is realized through the closed acoustic duct; efficiency of transmission of acoustic pressure varies with the morphology of the middle ear. This is provided by anatomical changes of auditory ossicles and a character of their arrangement in the tympanic cavity. The definite resemblance of macro- and micromorphology of the cochlea has been found in all examined species except dolphins. Resemblance of morphology of peripheric parts of the hearing analyzer in the course of evolution developed in forms belonging to different phylogenetic stocks but with the similar mode of life. These features define the effective functioning of the ear in different environments.

Soom, A., J.G. Bollinger, and O.J. Rongstad. 1972. Studying the effects of snowmobile noise on wildlife. Pages 236-241 in Proceedings Internoise 72. Washington, DC.

The effects of snowmobile noise on the movements of eastern cottontail rabbits (Sylvilagus floridanus) and white-tailed deer (Odocoileus virginianus) in Wisconsin were studied using radio-collared animals. Movements of seven rabbits in an isolated woodlot (14.5 acres) and 20 deer in a tamarack (Larix spp.) swamp revealed that neither the noise (35-95 dBA) nor presence of the snowmobiles caused the deer or rabbits to leave the areas that they normally inhabited; however, the presence of snowmobiles increased animal movements within and near their home ranges.

Stadelman, W.J. 1958. Observations with growing chickens on the effects of sounds of varying intensities. Poult. Sci. 37:776-779.

Broiler chickens were exposed to recorded airfield noise and aircraft flyovers from the start of brooding until 10 weeks of age. Weight gain, feed efficiency, meat tenderness and yield, and mortality were similar to controls. Loss in a pen of broilers is more likely to occur from an isolated low-level flyover than from continuous noise resulting from close proximity to an airfield.

Stadelman, W.J. 1958. The effect of sounds of varying intensity on hatchability of chicken eggs. Poult. Sci. 37:166-169.

Recordings of aircraft flyovers were played for 5 minutes out of every 20 minutes for 12 hours daily during incubation of chicken eggs. Sound intensities of 96 dB in the incubators had no measurable effect on hatchability or quality of chicks produced. Sound intensities of 115 dB were effective in interrupting brooding of 11 of 12 hens exposed to recorded flyovers.

Stebbins, W.C. 1978. Comparative biology of hearing in the mammals. J. Acoust. Soc. Am. 64(Suppl. 1):S15. [Abstract.]

The sense of hearing has become highly developed and specialized in the mammals relative to the other tetrapods. Increases in absolute sensitivity to acoustic stimuli (in the audible frequency range) and enhanced differential acuity to the different dimensions of auditory stimuli such as frequency and intensity have contributed to the success of the mammals as a group. Evolutionary changes in the structure of the middle ear conducting system, in the cochlea, and, to a lesser extent, in the central nervous system are presumed responsible. The considerable variation in auditory capabilities in the various orders and families reflects the different selective pressures that have played a major role. In some mammals, orientation and navigation have emphasized extended high-frequency sensitivity, while in others the obvious adaptive value of tightly knit social organization has placed a premium on the fine discrimination of the small but significant changes in the acoustic patterning of intraspecific communication sounds.

Stephens, D.B. 1980. Stress and its measurement in domestic animals: a review of behavioral and physiological studies under field and laboratory situations. Advances Vet. Sci. Comp. Med. 24:179-210.

This paper describes the nervous and endocrine mechanisms enabling organisms to respond to environmental stimuli (stressors). The immediate response is stimulation of the sympathetic nervous system, resulting in release of hormones from the certain adrenal glands. Behavioral and physiological responses of domestic animals to various stimuli are discussed.

Stewart, B.S. 1982. Studies on the pinnipeds of the southern California Channel Islands, 1980-1981. Hubbs-Sea World Res. Inst., San Diego, CA. Tech. Rep. No. 82-136. 117 pp.

Aerial and ground surveys of pinniped populations on San Nicolas and San Miguel Islands were conducted during 1980-1981. Population estimates of northern elephant seals (*Mirounga angustirostris*), California sea lions (*Zalophus californianus*), harbor seals (*Phoca vitulina*), and northern fur seals (*Callorhinus ursinus*) are included in this report to provide baseline data for future studies on the potential effects of sonic booms expected to be produced by launches of the space shuttle over the islands. In addition, breeding elephant seals and sea lions were exposed to loud impulse noise created by a carbide pest control cannon to simulate actual sonic booms. Distances of seals from the sound source varied from 5-100 m. Sound pressure level was 145.5 dB(A), 146.9 dB(flat), 20 uPa at 5 m from the cannon and 115.6 dB(A), 125.7 dB(flat), at 50 m from the cannon. The intensity and duration of behavioral responses of each species varied by sex, age, and season. More male elephant seals (74%) reacted with alert behavior than females (65%); only 26% of the nursing pups reacted. Animals returned to normal activity within a few minutes and no habituation to the sound, movement, trampling of pups, or increase in threat displays was observed. Alert reaction from human intrusion lasted longer than reactions from simulated booms.

During the nonbreeding season, over 70% of the sea lions left the haul-out area and went down to the surfline after a simulated boom. During the breeding season, 60%-95% of the females were alert for about a minute after a boom; few males reacted to the noise. No trampling of pups was observed and females moved less than 1 m from their pups. General observations of birds indicated that most birds within 100 m of the cannon flushed and circled the site. Within 2-10 minutes after the simulated boom, birds returned to roost or continued their previous activities.

Stewart, B.S. 1983. Studies on pinnipeds on the southern California Channel Islands, 1982-1983. Hubbs-Sea World Res. Inst., San Diego, CA. Tech. Rep. 83-154. 145 pp.

Populations of pinnipeds (seals and sea lions) were studied at San Miguel and San Nicolas Islands during 1978-1983 as part of the environmental assessment for the space shuttle. San Miguel Island will receive sonic boom impact from SST launches at Vandenberg Air Force Base while San Nicolas is not expected to be impacted. There is some movement of bre ding and nonbreeding animals between the two islands; therefore, prediction and study of the effects of SST sonic booms on pinnepeds at San Miguel Island should include considerations of the dynamics of populations at San Nicolas Island. Normal pinniped population processes studied at San Nicolas Island will also aid in predicting the effects of SST sonic booms on populations at San Miguel Island. This report presents results of eight studies on the population dynamics of marine mammals in the California Channel Islands. The populations of many of the species studied are increasing at a rapid rate. Space may become a limiting factor for these populations within a few years, about the time when space shuttle launches over the Channel Islands are expected to begin. These background studies will provide needed data so the population parameters, independent of space shuttle activity, can be examined.

Stockwell, C. A., and G. C. Bateman. 1987. The impact of helicopter overflights on the foraging behavior of desert bighorn sheep (Ovis canadensis nelsoni) at Grand Canyon National Park: final report. Natl. Park Serv. Washington, DC. 39 pp. [Unpubl. ms.]

Data were collected on desert bighorn sheep (Ovis canadensis nelsoni) foraging behavior in the presence and absence of helicopter overflights at Grand Canyon National Park in Arizona. Bighorn incurred a 17% reduction in foraging efficiency when helicopters were present. Helicopter presence also accounted for a 50% increase in the number of steps bighorn took during 5-min foraging bouts. The influence of helicopters on foraging varied seasonally. In the winter, foraging efficiency was reduced 42%. During spring, bighorn in closer proximity to aircraft appeared to be more vulnerable to helicopter disturbance. A 14% reduction in foraging efficiency was reported for bighorn inhabiting upper strata (300-430 m below helicopters flying at rim level), versus no significant differences for bighorn inhabiting lower levels (430-700 m below helicopters). The potential biological implications of these results are discussed and general management recommendations are presented.

Subcommittee on Animal Response, Committee on SST-Sonic Boom. 1970. An annotated bibliography on animal response to sonic booms and other loud sounds. Natl. Acad. Sci., Natl. Res. Council, Washington, DC. 24 pp.

The annotated bibliography includes abstracts of papers that discuss animal response to sonic booms (30 papers), impulse-type loud noises (7 papers), and steady-state loud sounds (69 papers). An evaluation, comparison, or discussion of the available literature is not included.

Sugawara, H., F. Aoyagi, and A. Kazushi. 1979. Effects of noise on the EEG and lactation in goats. J. Faculty Agric., Iwati University 14(4):319-336.

Experiments were carried out on five lactating Saanen goats to clarify the effects of noise-loading on the electroencephalogram (EEG), milk yield, and milk composition. Noise sources were simple sounds of 3 kHz and a complicated sound consisting of highway noise, wireless talk, and jet noise; noise intensity varied from 60 to 98 phons. The less time after parturation, the greater the effect of noise on milk yield. The concentration of butter fat in some samples increased after noise exposure, but that of total dry matter and crude protein remained almost unchanged.

Tavolga, W.N. 1982. Auditory acuity in the sea catfish (Arius felis). J. Exp. Biol. 96:367-371.

Frequency discrimination limens and signal-to-noise ratios were determined for the sea catfish (Arius felis), using avoidance-conditioning techniques. The lowest frequency discrimination limens had values of about 2.5% at 100 Hz. Other determinations were 3.5% at 200 Hz and 5% at 400 Hz, but these values were significantly greater if the test frequencies were higher than the reference. Signal-to-noise ratios were 14 dB at 100 Hz, 18 dB at 200 Hz, and 24 dB at 400 hz, with reference to the spectrum level of broad-band noise. These findings, and previous measurements of acuity, are discussed in relation to echolocation in the sea catfish, which involve sounds in the 100- to 200-Hz range.

Teer, J.G., and J.C. Truett. 1973. Studies of the effects of sonic boom on birds. Dept. Transportation Rep. No. FAA-RD. 90 pp.

A field study was conducted near Glen Rose, Texas, to determine if occurrence of sonic booms created by overflying aircraft was adversely affecting reproduction of wild birds. Several measures of reproductive success in mourning doves (Zenaida macroura), mockingbirds (Mimus polyglottos), cardinals (Cardinalis cardinalis), and lark sparrows (Chondestis grammacus) were compared between a test area and a control area. The test area was subject to sonic booms occurring two or three times a week; the control area was essentially free from sonic boom disturbance. In the final analysis, the authors could find no evidence that sonic boom disturbance affected phases of bird reproduction. Studies of the effects of pressure on growth, reproduction, and mortality of bobwhite quail were made in the laboratory with equipment designed

to deliver pressure treatments under controlled conditions. Results of these experiments showed that the pressures had no effects on hatching success, growth rates, or mortality.

Terhune, J.M., M.E. Terhune, and K. Ronald. 1979. Location and recognition of pups by adult female harp seals. Appl. Anim. Ethol. 5:375-380.

Harp seal (Phagophilus groenlandicus) cows use visual, auditory, and olfactory clues to locate and identify their pups. Identification is made at a close range and the pups are approached from a distance in a random manner. The topography of the ice supporting the pups changes frequently. These changes probably preclude or reduce the use of spatial memory by the adults. Because the pups cannot be identified at a distance, and because of the absence of stable landmarks, the adult must probably remain relatively close to her pup at all times. The large number of pups in the area suggests that random searching will not be efficient. The ability of various mammalian species to use spatial memory may well influence their modes of locating and identifying their young.

Travis, H.F., J. Bond, R.L. Wilson, J.R. Leekley, J.R. Menear, and C.R. Curran. 1974. Effects of real and simulated sonic booms upon reproduction and kit survival of farm-raised mink (Mustela vison). Pages 157-172 in Proceedings of the International Livestock Environment Symposium, Lincoln, Nebraska. Am. Soc. Agric. Eng., St. Joseph, MI.

A study was conducted on Mitkof Island, Alaska, in 1970 to determine the effects of real and simulated sonic booms on late pregnancy, parturition, early kit mortality, and subsequent growth to weaning of farm-raised mink (Mustela vison). The study involved 350 yearling and 148 2-year-old females and their progeny (1,845 kits). Treated animals received either three real sonic booms (averaging 294 N/m^2 overpressure) or three simulated sonic booms (averaging 167 N/m^2) on the day approximately 40% of the females in each group had whelped. Booms occurred over a 60-minute period; the second boom was 45 minutes after the first, and the third was 15 minutes later. The booms caused transient structural vibrations of 10 m/sec^2 or less on the wooden nest boxes. Mean length of gestation, mean number of kits born alive per female whelping, mean number of kits born alive per female, and mean weights of kits at 49 days of age were similar among treatment groups and the control group. The observable behavioral reaction of female mink exposed to real or simulated sonic booms was brief and had no apparent long-term effect on the health and well-being of the females and their newborn kits. Most mink returned to preboom activities within 2 minutes after each boom and appeared to habituate to the acoustic stimuli and vibration of sonic booms after exposure to only three booms in the span of 1 hour. No panic behavior, packing of kits, or killing of kits was observed during the boom tests. General health and productivity of the mink were below average. The farm mink were from a strain selected for the recessive Aleutian gene and, thus, were less hardy and had more difficulty combatting bacterial infections than other strains of mink. However, the health of the mink was similar among the control group and experimental treatment groups and was not related to the effect of sonic booms.

Travis, H.F., G.V. Richardson, J.R. Menear, and J. Bond. 1968. The effects of simulated sonic booms on reproduction and behavior of farm-raised mink. U.S. Dept. Agric. Res. Serv. 44-200. 18 pp.

Mink (Mustela vison) were exposed to simulated sonic booms with overpressures from 0.5-2.0 psf. Litter sizes of boomed mink were larger than those of nonboomed mink. Autopsies of kits revealed they died from natural causes, and no evidence of death was related to booming.

Tsuchiya, A., Y. Ohta, M. Nishimura, and C. Miyazaki. 1981. Correlation analysis of man-made underwater sound and fish behavior. J. Fac. Mar. Sci. Tech., Tokai University 14:325-341.

A method of system analysis was used to assess the influence of manmade sound on fish behavior in coastal waters. The quantitative expression of fish response against sound principally was obtained by the results of correlation between sound and variables of fish behavior. The principle of system analysis, experimental design method, and mathematical equations are presented. Results of experiments with crucian carp (Carassius carassius) and gray mullet (Mugil cephalus) indicated average response time of 0.4-1.4 seconds and 3 seconds, respectively. The response of fish to sound could be expressed quantitatively by the correlation analysis.

U.S. Air Force. 1985. Final Environmental Impact Statement: establishment of the Gandy Range extension and adjacent restricted airspace as an area for supersonic flight training, Hill AFB, Utah. Public Affairs Office, Hill Air Force Base, Utah. 96 pp. + appendices.

The Air Force needs additional area to conduct supersonic flight training for aircraft associated with Hill Air Force Base, Utah. The preferred alternative to meet this requirement is to designate an area of existing military airspace adjacent to the area currently used for supersonic training flights. The existing area accommodates a maximum of 614 supersonic sorties per month. The resulting supersonic area, a combination of the existing plus the proposed areas, would accommodate about 768 supersonic sorties per month. The new land area beneath the airspace is predominately Bureau of Land Management land, with an estimated 50 residents. As a result of public comments on the draft Environmental Impact Statement (EIS), the Air Force substantially reduced the number of proposed additional sorties from about 400 to 150 per month, the number of people potentially affected from 350 to 50, and the land area from 2,478 to 1,360 mi^2. Environmental impacts discussed in the final EIS include the sonic boom effects on animals. The area contains several threatened and endangered species, including peregrine falcons (Falco peregrinus), bald eagles (Haliaeetus leucocephalus), spotted bat (Euderma maculatum), and steptoe dace (Relictus solitarius). The EIS discusses a few studies related to the impact of sonic booms on wildlife, and states that "knowledge of the effects are limited, but it appears that sonic booms do not pose a significant threat to wildlife." However, the EIS also states that "questions on long-term protracted exposure and sublethal responses remain to be studied." A joint study between the Air Force and the Utah Division of Wildlife Resources was recommended to study the effects of sonic booms on transplanted species [e.g., bighorn sheep (Ovis canadensis), peregrine falcon (Falco peregrinus)] in the Deep Creek Mountain Wilderness Area.

U.S. Army Corps of Engineers. 1979. Environmental assessment, seaplane use of project waters, Lake Ashtabula, Baldhill Dam, Sheyenne River, Baines County, North Dakota. U.S. Army Corps of Engineers, St. Paul, MN. 15 pp.

The Corps of Engineers (COE) proposed allowing seaplanes to use the Lake Ashtabula reservoir on the Sheyenne River, North Dakota. In the environmental assessment (EA) of the proposed seaplane landing area, noise levels were briefly mentioned: "operation of a seaplane at the reservoir would generate additional noise greater than any vehicle or boat now being used" and "this noise would disturb wildlife, especially waterfowl, and residents and visitors at the lake." The major impact to waterfowl was expected to be scattering of birds on the lake during spring and fall migration. The EA referred to no previous studies concerning impacts of noise; the COE determined that an environmental impact statement was not required for this project.

U.S. Department of the Interior. 1969. Environmental impact of the Big Cypress Swamp Jetport. U.S. Dept. Inter., Washington, DC. 155 pp. [Unpubl. Rep.]

The environmental impact analysis of the proposed Big Cypress Swamp Jetport in Florida, about 36 miles west of Miami, concluded that development of the facility would lead to land drainage and development for agriculture, industry, housing, transportation, and services in the Big Cypress Swamp that would "inexorably destroy the south Florida ecosystem and thus the Everglades National Park." The report includes a description of the area, potential impacts of the proposed site, and recommendations for further action. Impacts of noise are discussed in general terms. A more detailed discussion of potential bird strike hazards is presented.

Van den Berg, A.V. 1985. Analysis of the phase difference between particle motion components of sound by teleosts. J. Exp. Biol. 119:183-197.

The hypothesis that fish may remove 180 degree ambiguities concerning the sound source direction by timing analysis between particle motion components was addressed. Analysis of the phase difference between the horizontal (v) and the vertical (w) components of the particle velocity of sound signals by teleost fish was investigated by cardiac conditioning. Standing wave sound stimuli (90 Hz) were used with phase difference equal to plus or minus 90 degrees and equal amplitudes of v and w. The water particles moved along circular trajectories for such stimuli; however, the direction of revolution was reversed in the two stimuli. These stimuli were discriminated by one whiting (Merlangus sp.), one catfish (Ictalurus sp.), and several cod (Gadus sp.), indicating that these teleosts were able to discriminate signals on a pure timing cue. If the w/v ratio was lowered, the cod could discriminate the resulting elliptical motions on the direction of revolution down to a w/v ratio of -12 dB. Moreover, down to the same w/v ratio the cod discriminates an elliptical particle motion signal from a pure translatory particle motion signal. At this level, the threshold signal-to-noise ratio for the w component was exceeded by 9 dB. Apparently, phase analysis can be limited by "cross talk" between horizontal and vertical particle motion detectors. The results are discussed with respect to models of directional hearing by fish.

Van Dijk, T. 1973. A comparative study of hearing in owls of the family Strigidae. Netherlands J. Zool. 23(2):131-167.

On the basis of conditioning experiments, audibility curves were obtained for six tawny owls (Strix aluco) and six long-eared owls (Asio otus). In addition, cochlear potentials, evoked by tone-bursts, were derived. The size of the potentials was correlated to the applied sound levels. Curves of varying frequency and sound pressure at constant size of the cochlear potential were obtained, showing to some extent the owls' frequency response. The audible frequency ranges found appeared to rank among the best high-frequency hearing presently known in birds. The owls' hearing was extremely sensitive, with lowest thresholds of -4 dB (tawny owl) and -1 dB (long-eared owl). The frequency range of very good sensitivity extended from about 0.4-7 kHz in tawny owls and from about 0.5-8 kHz in long-eared owls (thresholds for these frequencies did not exceed -14 dB). In additional experiments, behavioral audibility curves were also collected from nine owls belonging to eight other species of which the external ears are less specialized than those of tawny and long-eared owls. The best hearing individuals showed a sensitivity of the same order as that found in tawny and long-eared owls; however, their frequency range of very high sensitivity never exceeded 6 kHz.

Vasil'ev, B.D., and S.V. Smirnov. 1981. Auditory sensitivity of turtles. Moscow University Biol. Sci. Bull. 36(4):9-14.

The middle ear of turtles, which perceives sounds in air by means of the normal tympanal-stapedial principle, is distinguished by an extremely thick tympanal membrane; a long, monolithic columellar system that penetrates the quadrate bone; and poor adaptive variabilty of the auditory analyzer. Experiments were conducted to determine the characteristics of the middle-ear elements in four species of Euro-Asian turtles: the fresh-water turtle (Emys orbicularis), Caspian turtle (Clemmys caspica), the steppe tortoise (Testudo horsfieldi), and the spur-thighed Mediterranean land tortoise (Testudo graeca). The evoked potentials recorded from the medullary auditory nucleus of these species indicated that their perception of sounds was limited to a narrow range of low frequencies (100-150 Hz), and that their capacity for discriminating the character of auditory stimuli (noise and pure tones) and evaluation of their amplitude-frequency and temporal parameters is limited.

Vasscut, P., and F. Devriere. 1975. Study of metabolic response variation to an acoustic agression. Natl. Tech. Inf. Serv., Springfield, VA. 34 pp.

The metabolic response of rats to an acoustic variation was investigated using a noise generator simulating sonic boom waves of N profiles. The operational conditions and experimental setup are presented. Experimental results, including the dosage of blood, plasma, potassium, and glucose, as well as the dosage of catecholamines in rat urine after exposure to N acoustic waves, are discussed. A relation was found between the recovery time to return to base metabolism level and the peak pressure. In addition, isoeffect curves displaying peak pressure and exposure time versus the excretion of urine catecholamine were established.

Ward, D.H., R.A. Stehn, D.V. Derksen, C.J., Lensink, and A.J. Loranger. 1986. Behavior of Pacific black brant and other geese in response to aircraft overflights and other disturbances at Izembek Lagoon, Alaska. U.S. Fish Wildl. Serv., Alaska Fish Wildl. Res. Center, Anchorage, Alaska. 34 pp. [Unpubl. Rep.]

Observations in fall, 1984, indicated that Pacific black brant (Branta bernicla nigricans), emperor geese (Chen canagica), and Canada geese (Branta canadensis) were disturbed by helicopter traffic across Izembek Lagoon near the western end of the Alaska Peninsula. Air traffic was associated with an existing 3,050-m runway at Cold Bay (<15 km from the east side of the lagoon) used in conjunction with Outer Continental Shelf petroleum exploration in the St. George Basin. U.S. Fish and Wildlife Service personnel were concerned that disturbance-induced flight might reduce brant foraging efficiency and feeding time. In a preliminary study undertaken from 23 September to 21 October 1985, responses of geese to aircraft and other disturbances were observed from six sites along the shoreline of Izembek Lagoon, during a total of 260 hours. A total of 623 possible disturbance events for all geese was recorded, with 65% of these events caused by jets and propeller aircraft, 14% by helicopters, 14% by gunshots, 2% by people, 2% by boats, 2% by eagles, 1% by falcons, and less than 1% each by land vehicles and foxes. All but 22 events were human-induced disturbances. The level of behavioral response differed greatly among the various disturbance stimuli. Eagles, boats, and humans on foot caused a greater percent of flight in brant flocks than any category of aircraft; however, the lateral distances to these stimuli were much less than that typical for aircraft overflights. The Bell-206-B helicopter seemed to provide a greater degree of behavioral flight response compared with similar controlled overflights by single-engine, fixed-wing aircraft. This report was preliminary and further data collection and analysis will continue.

Wells, M.C., and P.N. Lehner. 1978. The relative importance of distance senses in coyote predatory behaviour. Anim. Behav. 26: 251-258.

The purpose of this study was to determine the relative importance of vision, audition, and olfaction to hunting coyotes (Canis latrans). The durations required for five coyotes to locate rabbits in an enclosed room were measured. The visual, auditory, and olfactory stimuli emitted by the rabbits were eliminated individually, in pairs, and altogether; the coyotes' preference for use of these senses was tested. The relative importance of these three senses in order of decreasing importance was: vision, audition, and olfaction.

Werner, Y.L. 1972. Temperature effects on inner-ear sensitivity in six species of iguanid lizards. J. Herp. 6:147-177.

Temperature effects on the function of the inner ear in six species of lizards (Anolis lionotus, Crotaphytus collaris, Diposaurus dorsalis, Sceloporus occidentalis, Uma scoparia, Uta stansburiana) are defined and correlated to the lizards' known ecological temperature preferenda. Pure tones (50-15,000 Hz) were presented to the anesthetized lizard's external ear. Curves of the sound intensity required to elicit a standard response of the alternating potentials of the chochlea were mostly within 20-40 C. In all species, the basic shape of the sensitivity curve persists at all temperatures, showing the greatest sensitivity in a central region that varies with the species within a range of 400-4,000 Hz. Hearing appears to be best at ecological optimal temperatures.

Wever, E.G., and E.A. Peterson. 1963. Auditory senstivity in three lizards. J. Auditory Res. 3:205-212.

Hearing sensitivity of three iguanid lizards (Uma notata, Sceleporus clarki, Urosaurus ornatus) from the Arizona desert region was determined by the cochlear potential method. Hearing sensitivity curves for the three species were similar, with greatest sensitivity around 700-2,000 Hz and regularly decreasing sensitivity for lower and higher tones. The effectiveness of the middle ear in the transmission of sounds to the inner ear is discussed.

White, C.M., and S.K. Sherrod. 1973. Advantages and disadvantages of the use of rotor-winged aircraft in raptor surveys. Raptor Res. 7(3/4):97-104.

Jet engine and piston engine helicopters were used to survey bald eagles (Haliaeetus leucocephalus), golden eagles (Aquila chrysaetes), peregrine falcons (Falco peregrinus), gyrfalcons (Falco rusticolus), and rough-legged hawks (Buteo lagopus) nesting off cliffs or hillsides in open terrain in Alaska during 1964 and 1969-1973. General observations of raptor behavior in response to the rotary-winged aircraft were noted. The high-frequency whine made by some of the jet engine helicopters seemed to be much less disturbing to nesting raptors than the low-frequency noise of the piston-powered craft. Birds were least disturbed when the helicopter flew parallel to a cliff at an

initial distance of about a half mile out with gradual approach toward the nest. Birds often continued to feed their young or loaf on a cliff when approached in this manner. Birds surprised suddenly by the presence of a helicopter appearing from over the top of a cliff usually panicked and exhibited frantic escape behavior. Approach from above was not nearly as alarming to the bird, especially when they could see the approach from a considerable distance. Disturbance just before egg laying, during egg laying, and during incubation was more deleterious than disturbance during the nestling stage. The authors recommended helicopter surveys of nesting raptors after the young had hatched, but before the young were ready to fledge. The presence of a helicopter too close to a nest late in the nesting season may force young birds into premature fledging. Fair-weather days were recommended over inclement weather for clearer observation and to avoid chilled eggs or young if the adults are flushed off the nest in cold, wet weather. Experienced pilots, familiar with maneuvering the aircraft in wind drafts, were also recommended. Approach from upwind is preferred, to avoid inadverdently flushing birds into the helicopter. Raptor attacks on fixed-wing aircraft appear to be more frequent than attacks on helicopters. Productivity estimates of raptors from areas not surveyed by helicopters were similar to productivity estimates of raptors surveyed by helicopters.

Wilbur, S.R. 1978. The California condor, 1966-76: a look at its past and future. U.S. Dept. Inter., Fish Wildl. Serv., Washington, DC. N. Am. Fauna. No. 72. 136 pp.

The California condor (Gymnogyps californianus) was studied on about 900 field days between 1966 and 1976. In addition, some 1,000 items of literature, specimen records from 56 museums, and 3,500 reports of condor sitings by cooperators were analyzed. Distribution does not appear to have changed significantly since the 1930's, although some areas within the species' range have become usable condor habitat. Two subpopulations of condors exist, one occupying the Coast Range Mountains, and the other found in the Transverse Ranges, Tehachapi Mountains, and Sierra Nevadas. Within each subpopulation area, condors have well-defined seasonal movements. The surviving wild population was estimated at 45 condors in 1976, a decline of about 20% since 1965 and probably over 50% since 1940. No reliable population estimates are available before the 1940's, but it appears that a major decline occurred between 1880 and 1920. Shooting and specimen collecting were the primary causes of the early decline, and shooting continued as a major problem into the 1960's. Recent declines are a result of inadequate production; annual surveys indicate that only 16 young have been produced since 1968. Causes of low production are unknown but inadequate food supply, environmental contaminants, and disturbance from air traffic and petroleum extraction are suspected. Several references to disturbance from sonic booms and low-level aircraft have been documented. While sonic booms are not expected to cause breakage of eggs, disturbance could cause the incubating adult to flush from the nest and knock the eggs out of the nest. A recovery plan for the condor is in operation; steps have been taken to supplement food supplies, preserve nesting and roosting habitat, and protect surviving birds from man-caused

mortality or disturbance. The condor's prospects of recovery in its natural habitat seem bleak; a captive propagation program is proposed to supplement wild production.

Wilkins, M.E. 1972. Sonic boom effect on fish: observations. National Aeronautics and Space Administration, Ames Research Center, Moffett Field, CA. Rep. No. N72-24065. 9 pp.

Motion pictures of fish in a small tank at the time a bullet travelling 1,200 m/sec passed a few centimeters above the tank indicated that the fish sensed the passage of the shock wave, but suffered no "ill effects." The pressure rise at the bow shock wave was 0.26 atm or 275 times that associated with a strong sonic boom from a supersonic transport.

Woolf, N.K., J.L. Bixby, L., and R.R. Capranka. 1976. Prenatal experience and avian development: brief stimulation accelerates the hatching of Japanese quail. Sci. 194:959-960.

One 2-hr exposure to auditory stimulation (80 dB, 0.1-8 kHz) during the last 3 days of incubation accelerated the hatching of Japanese quail (Coturnix japonica). The data provided evidence that short-term prenatal sensory stimulation can affect the development of an avian embryo.

Yahya, S.A. 1978. Hearing ability of browntree snake (Dendrelaphis tristis). J. Bombay Nat. Hist. Soc. 75:930-931.

The author noted an observation of a browntree snake (Dendrelaphis tristis) that appeared to respond to the sound of an airplane passing overhead. As soon as the sound was heard by the author, the snake lifted up its head, "as if trying to see the source of the sound," making a 90 degree angle with its body, and remained in this position until the sound faded; the plane was not visible to the author through the canopy cover. Dr. Carl Gans commented on the author's observation, he stated that snakes can hear quite well to 15,000 Hz., but that "it would be surprising if the snake did indeed present an obvious behavioral response" to the sound of a passing plane. Dr. Gans recommended that the incidental observation be checked out by experiment because the snake might have responded to movements of the wind or to chemical cues, which the author could not have observed.

Zelick, A., and P.M. Narins. 1980. Behavioral response of treefrogs to low-level sound stimuli. J. Acoust. Soc. Am. 68(Suppl. 1):S97. [Abstract.]

Acoustic avoidance behavior was demonstrated in a natural population of the neotropical treefrog (Eleutherodactylus coqui). The threshold for acoustic avoidance at different frequencies was in the range of 230 to 3,420 Hz. Tones of 605 to 2,000 Hz were uniformly above threshold when presented at a level of 60 to 70 dB SPL. Below 665 h threshold dropped at 14 dB per octave to a

maximum sensitivity of 41 dB SPL at 230 Hz. Tones of 3,420 Hz (approximately the third harmonic of the first note of the advertisement call) failed to elicit a response even at high levels (over 81 dB SPL in one case). Single tone stimuli (1 to 2 seconds duration), spaced at the frog's spontaneous call interval (2 to 3 seconds), were presented to frogs. The frog redistributed his calls in time such that they fell almost exclusively within the brief time window between tone bursts, thereby avoiding overlap with the tone. The average background noise level at the frog's calling site was 39 dB SPL at 500 Hz, 59 dB SPL at 1,000 Hz, and 66 dB SPL at 2,000 Hz. Thus, the avoidance behavior was observed at stimulus levels barely exceeding the noise floor of the frog's environment.

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16. Abstract (Limit: 200 words)

The purpose of this document is to provide an information base on the effects of aircraft noise and sonic booms on various animal species. Such information is necessary to assess potential impacts to wildlife populations from proposed military and other flight operations.

To develop this document the National Ecology Research Center conducted a literature search of information pertaining to animal hearing and the effects of aircraft noise and sonic booms on domestic animals and wildlife. Information concerning other types of noise was also gathered to supplement the lack of knowledge on the effects of aircraft noise. The bibliographic abstracts in this report provide a compilation of current knowledge. No attempt was made to evaluate the appropriateness or adequacy of the scientific approach of each study.

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